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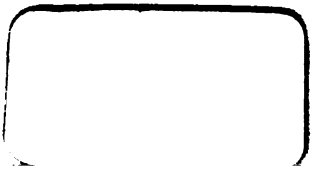

ENGINEERS' AND FIREMEN'S HANDBOOK

THIS VOLUME IS A PRACTICAL MANUAL FOR ENGINEERS AND FIREMEN TREATING OF THEIR DUTIES AND RESPONSIBILITIES AND THE DETAILS NECESSARY TO BE OBSERVED BY THEM IN THE OPERATION AND HANDLING OF SIMPLE, COMPOUND AND OIL BURNING LOCOMOTIVES, AND INCLUDING FULL PROGRESSIVE EXAMINATIONS (QUESTIONS AND ANSWERS) FOR THOSE SEEKING TO QUALIFY AS LOCOMOTIVE ENGINEERS. PROFUSELY ILLUSTRATED WITH MANY DRAWINGS MADE EXPRESSLY FOR THIS WORK.

FORMING ONE OF THE SERIES OF VOLUMES COMPRISED IN THE REVISED AND ENLARGED EDITION OF

THE SCIENCE OF RAILWAYS

BY

MARSHALL M. KIRKMAN

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INTRODUCTION.

The books that make up the "SCIENCE OF RAILWAYS," of which this is a part, have much to say, directly and indirectly, about the Equipment and Train Service of railways. Both these subjects bear directly on the duties and responsibilities of engineers and firemen. It is as impossible to afford a separate and connected account of such duties as it is to afford such an account of the duties of superintendents or comptrollers. Railway service laps and interlaps in every direction, and the engineer and fireman to fully understand their duties must also understand the things that are germane thereto. This requires that they should study railroading not piecemeal, but as a whole.

It was the impossibility of separating the duties of particular departments of the service and describing them apart that first constrained me to take up the subject as a whole. I started out to describe particular branches of the service, but quickly found that their connection with the others was so close as to render a description of the whole necessary. Thus I was led reluctantly and contrary to my original intention to take up the subject in its entirety.

What I have been compelled to do, others, who seek to fully inform themselves in regard to particular branches of the service, will also be compelled to do.

While there are many engineers and firemen who take this comprehensive view of the subject, others believe their field lies more apart and that, therefore, it is susceptible of separate delineation and study. There is much interesting and valuable literature extant on the subject of the duties of engineers and firemen, but for the reason stated, it only partially explains their offices. This does not, however, lesson its value, so far as it goes. It is simply incomplete.

Knowledge of the locomotive and how it is operated is only one of many things engineers and firemen must know. They must also be familiar with train regulations, signals, methods of dispatching trains and kindred knowledge. Such things are fundamental. Moreover, as their duties bring them in daily contact with the equipment, they must know something of its construction, care and maintenance. The wider their knowledge, the greater the probability that they may some day become department directors instead of operatives merely. Nor need their ambition be thus restricted. The nature of their duties affords an admirable

opportunity for acquiring the knowledge required by superintendents and managers of railroads. All that is needed is that he who sets out to familiarize himself with the locomotive shall keep on until he becomes acquainted with the needs of other branches of the service. The task is difficult, but not insurmountable. The knowledge may be acquired by experience, study, observation, inquiry and the thousand and one devices ambitious men adopt to further their ends.

A man who seeks merely to be a fireman, and then an engineer, and afterward perhaps, a foreman, may be satisfied with a mechanical or perfunctory knowledge of the railway world, but such knowledge is not sufficient even for this limited field. However, he can possibly get on thus without scandalizing the service, or seriously jeopardizing the interest of his employer, but if he expects to occupy a position of greater power and influence, he must study railroading as a whole. Only thus can he comprehend the spirit and practices that animate the service, or cope with the many men of talent who fill its offices.

To be an officer of a railroad, or to fill a position of responsibility in connection therewith, requires that the incumbent shall understand the science of government. This science is in essential things alike as regards public and private

corporations. To know how to govern a country or city well, is to know how to govern a great railroad well with its vast army of employes and widely extended and complicated interests. The man who seeks preferment in either must understand how governments are formed and how best carried on for the common good. He must know much about the checks and safeguards that experience proves to be needed in order to secure a strong and pure government. Such knowledge, as I have said, constitutes a part of the science of railroads, and no man is fully capable of being an officer of a railroad or of holding a position where he must come in contact with the public, without possessing it. This feature of the situation I have sought to explain in my books as conscientiously as I have the basis of rates, safe conduct of traffic, or the faithful handling of a company's money, but the information is not to be found in any particular chapter or book. It permeates every part of the service and it is impossible to discuss any question without more or less reference to it. It is this fact which makes men familiar with the magnitude and homogeneousness of the subject, so impatient of those who think that there are departments and branches of the service that may be considered apart from the rest.

Those who work for railroads, no matter where, are interested in acquiring knowledge of every department of the service, and this not perfunctorily, but systematically. Their personal inter-

ests not only require that they should possess this knowledge, but the interests of their employer as well. The more the subject is studied, the more this truth will be apparent. I am not so presumptuous as to believe I have exhausted the science of railways in my books. If a book could be made exhaustive, there would never be but one written. The greatest value that any book possesses is the suggestions it affords the person who reads it. He may find many things upon perusing it, that he did not know before, or only surmised; others again that he had overlooked. He will be refreshed as by a bath, even though he has only acquired a morsel of original information from what he has read, for the reason that his knowledge will have been expanded by the thoughts to which his reading has given rise. Let railway men keep this in mind in reading books on railway and other subjects.

I have sought to treat my theme as fully as circumstances permitted. Where I do not wholly enlighten, I may be pardoned for believing that I have at least pointed the way.

There are few of the books that make up the "Science of Railways" that do not contain matter of more or less general interest and value to those who seek to be firemen and afterward engineers. However, if the latter position is the height of their ambition, then some of the books will not possess as much value as they would under other circumstances, but in every book may be found some account of the practices and

philosophy of railroading with which it is desirable every one should be familiar.

Much of the information that books on the general subject of railroads contain is not necessary to a fireman to enable him to creep up to the place of engineer, any more than salt is absolutely necessary to a potato; but he like every railway man, if lacking in the niceties of his profession (that only general knowledge can supply), will lack flavor and will seek in vain to reach the highest positions in the service.

From the foregoing it will be seen that a consecutive and separate account of the duties of engineers and firemen is impossible. However, there are particular duties imposed upon them that may be described apart. These I shall embody here. While incomplete, the matter is not the less valuable on that account, as it is replete with suggestions. This I may say with the greater freedom, as I am the editor, rather than the author. What I shall have to say is probably known to accomplished railroad engineers, but it is not known to those less favored, and yet they should be familiar with it, in order to be able to look forward with confidence to preferment in their calling. Furthermore, if instead of treating what I have to say as final, the student in search of knowledge will look upon it as rudimentary only and supplement it with acquisitions of his own, he will not only add greatly to his prospects as a railway man (by adding greatly to his value to his employer), but he will increase immeasurably

his ability to secure a position, if through any untoward circumstances, he finds himself without employment.

CHAPTER I.

THE LOCOMOTIVE THE KEY TO THE RAILROAD WORLD. QUESTIONS REGARDING SELECTION, TRIAL AND WORK OF THOSE IN CHARGE. THE VALUE OF SYSTEMATIC STUDY AND CAREFUL EXAMINATIONS TO THOSE WHO WOULD BECOME EFFICIENT ENGINEERS.

As the engine is the key of the railway world, so those who operate it share in its supreme importance. While admirable in outline and usefulness, it is after all only an aggregation of metal fashioned into many curious forms, but dead and incomplete without the guidance of the engineer and fireman. Like the world in the beginning when clothed in stillness and death, awaiting the light of day, so the locomotive stands apart, cold and dead, but under the inspiring influence of the Engineer and Fireman pulsates with life, forming not only a magnificent picture in itself, but one of the most useful implements ever designed by men for the use of men.

The locomotive is still in a state of evolution, and, sympathetically, those round about it are changing not only in the particulars of their duties, but in their aspirations and lives. The engineers and firemen of early days bore little resemblance to their brothers of the present

period. The latter have not only personally acquired greater skill, but they possess also the accumulated experience of those who have gone before them. It is no exaggeration to say that the fireman of to-day, even if a novice, is much superior in capacity to the engineers who had charge for a long time after railways were first operated. The first enginemen were by trade, blacksmiths and mechanics, who understood something about metals and machinery, but were ignorant of the uses of steam or the future possibilities of the locomotive. It was necessary to train men for the position. This process has been going on with ever accelerated speed from the first day up to the present moment. There is no end to the road. It grows wider and the horizon expands with each advancing step.

The firemen and engineers of railways constitute as highly a trained class of men as there are connected with the technical world of trade at the present time. Their knowledge and usefulness will increase with time and further experience. It is only reasonable to believe this because we know that possession of knowledge only intensifies the desires of men in this direction. Its acquisition by an ambitious man creates an unquenchable thirst for further light. His mind expands with his opportunities in this direction until the vacuum of the brain appears so much greater than its filled space that the wisest man becomes despondent at the meagerness and superficiality of his knowledge.

It is only the supremely ignorant man whose mind is at rest.

With each passing day, knowledge becomes more and more a necessity to men. The advantages the informed man has over his ignorant brother, are so great that the latter must likewise acquire knowledge or confine himself to the common drudgeries of life. This is what competition is doing, and it is thus showing itself as useful in this department of life as it has in the production and interchange of material commodities.

Men have no inherent love of study, but the taste grows, and if one man studies, all must eventually study or be outstripped in the race of life. Thus the ambition of a particular man starts the whole forward. When men acquire a desire to learn, moreover, their ingenuity supplements the efforts of others, and in this way accomplishes a double purpose, at once encouraging and beneficent.

As the driftwood carried to the coast of Spain suggested to Columbus the unknown world of America, so the questions and answers embodied further on herein will suggest a host of collateral ideas of great value both to the student and his employer. These inquiries measurably dispel the darkness, but do not fully light up the horizon. And so it is generally in reference to books. A great good that they serve is the thoughts they give rise to in the minds of readers. The capillary attraction of the human mind thus exemplified, if I may thus character-

ize it, has this attractive feature, that above the water line of acquired knowledge it ever attracts to itself, all that is necessary to nourish or expand it. It is this feature of the brain reaching beyond original limits, that has made man the arbiter of the world, and that makes all things an open book to him. The only difficult thing in his case is to get his mind in motion; once under way, it never ceases its inquiries until death silences its action.

In the case of engineers and firemen many methods have been devised for adding to their knowledge so that they may better serve themselves and the great industries with which they are connected. In some of the old countries of Europe, and particularly in France, technical schools have been established near the great shops by railroad companies, so that the children of employes may early in life be instructed in the trade they design following, and this under the immediate eye of their father. Thus, as they grow up, they associate themselves with him and afterward, when he is too old to work, succeed him in his calling. In this way, the child is brought at the most receptive period of its life into direct contact with the things that are afterward to occupy its mind exclusively. The advantage of this cannot be overestimated, for we all know that there is a particular period in life that is illuminated more brightly than any

other, when what we learn we do not forget nor undervalue. This period, to a great extent, forms the groundwork of every man's life. Consequently, if during such period light is thrown on the work that is afterward to occupy him, it exceeds in value knowledge acquired at any other period. For this reason, the benevolent intentions of the corporations in providing schools for the children of employes, will, it is reasonable to believe, be followed by the best possible results to themselves. However, the schools are not intended for the children of firemen and engineers alone, but for all employes engaged about the shops.

Usually the effort to educate men for engineers and firemen does not commence until the men have entered the service. This is where the great bulk of the railroads of the world take up the work of instruction. The method they follow in carrying out their object is as diversified as it is in other things connected with the service.

Formerly, applicants were put on the locomotive, and told to go to work, their preparatory instruction being of the simplest possible kind. In other cases, the fireman is compelled to serve a brief apprenticeship in the roundhouse. In still other cases, the preparatory period is more extended and the labor prolonged. Some companies go so far as to require a man who seeks to become a fireman to commence emptying clinker pits, cleaning and wiping engines, and

performing such mechanical duties in connection with the locomotive as occasion requires. If he shows adaptability and industry, he is after a while given an opportunity by being put on the Extra Firemen list. Here his action is carefully scrutinized. If he meets just expectation, he is in due course made a regular fireman, the assistant and second self of the engineer. Here, while he has his own work to do, and plenty of it, he has an opportunity to familiarize himself with the work of the engineer. The facility with which he does this, will depend upon his ability to learn and his desire to get on in the world, but assuming that he, not less than his older brother the engineer, is animated by an acute intelligence and a laudable ambition, he must also have, like the latter, good health, a strong body, and be free from intemperate habits. These latter qualities are more necessary to those connected with locomotives than to others in the service, although they are necessary to every man who expects to achieve success in life.

It goes without saying, that every man who seeks to be a fireman, or who expects to become an engineer, must have a good character.

The practice of examining into the qualifications of applicants before hiring them grows in popular practice every year. Men are scrutinized more carefully than formerly, and once having entered the service, greater intelligence is exercised in ascertaining their capacity and usefulness. This is especially true of those branches

of the service where technical skill is required and perfect trustworthiness needed. In the early days it was sufficient that an applicant for the place of fireman was able to perform the work, which, under the most favorable circumstances, is very severe. Afterward, as experience taught the necessity of it, railroad companies began to inquire into the antecedents of aspirants. By and by they got to inquiring about their habits, but railroads had been operated in America sixty years before it occurred to them to test the mental capacity and disposition of applicants by careful examinations. As this could not very well be done before applicants entered the service, it had to be done afterward. It took, in a general way, the shape of examinations such as characterize those of students of law and medicine. Meanwhile, the general trustworthiness of the employe was scrutinized and his mode of life, morals, temperament, steadfastness and general fidelity to duty carefully studied. If deficient in these latter respects, intellectual and physical endowments were not sufficient to outweigh objections. On the other hand, if he possessed all the moral qualities, and yet was deficient mentally and physically, he was not considered as affording good material for a fireman, and, prospectively, an engineer. Accordingly, if during the probationary period he broke down, or failed to answer the requirements of the service, he was told to go his way and in some field where his capabilities would be sufficient for the occa-

sion fix his life occupation. This, instead of being a hardship or injustice, has been found to be a kindness to applicants, because it anticipates subsequent failure and saves them the waste of time and mortification that would otherwise ensue.

It also saves the company, and incidentally the public, from the mishaps that attend the service of men inferior in mental and moral qualities. It not only enables the employer to promptly separate the capable from the incapable, but throws around the general public a measure of safety that carriers are always bound to consider.

In order to pass the examinations, careful study and preparation, and experience as well, are required. Applicants must at least have a good common school education, because this is required of engineers. Once having entered the service it is manifest that the efficiency of the incumbent may be greatly heightened by requiring him to commence at once systematically to study the problems of the business with which he is identified, and not solely, be it remembered, with a view of performing his present duties properly, but with the further view of his being promoted to the responsible position of engineer, at a given time, or thereafter when opportunity occurs. Methods of procedure vary on different roads, according to men's views of the subject. Some roads do not make any examinations at all, but the tendency is more and more in that direction

as their value becomes more and more apparent. The system which is elucidated further on, and which meets with the approval of some of the most experienced and talented Master Mechanics and Superintendents of Motive Power in the world, contemplates a careful and systematic course of study. First, however, the habits and antecedents of applicants are carefully inquired into, as I have intimated. Once the applicants have passed this ordeal, the full confidence of the company is accorded them and every facility afforded them to pursue their inquiries and studies so as to fit themselves for present and future work. Every official of the machinery department holds himself ready to answer questions or respond in other directions so far as it may be proper to aid applicants in this way.

After the applicant for the position of fireman has passed through the preliminary stages, whatever they may be, he is given a series of questions bearing directly on his future duties and responsibilities as an engineer. These he is expected to carefully study, and at the end of the time designated, go before the master mechanic or other authorized officer and answer them categorically, with such other questions of an incidental nature, as are pertinent to the occasion. However, the list of questions given him and the answers thereto constitute the examination in the main.

Having passed the first examination successfully, he is furnished a further list of questions he will be expected to answer. This constitutes the

second examination. Following this he is furnished the interrogatories which close the course of study.

In regard to the last examination, no one is ever sent for to take it, whom the master mechanic above him is not willing to accept as an engineer provided he successfully passes it. Another condition and a very proper one is that men sent forward for this examination shall be in their order of service, other things being equal. The final examination, which is so important, is usually conducted by a board appointed for the purpose. This insures impartiality and thoroughness, though the same thing can, it is apparent, be secured by an examination made by the master mechanic and his associates.

All the examinations having been passed and the applicant's work meanwhile having proven satisfactory, he is ready to take charge of a locomotive—is an engineer in fact, ready to fill the first position of the kind that offers. This is the goal he has sought. Such is the procedure.*

Different roads vary the details. Its merit is that it affords a course of study, which, with the practical experience of the fireman meanwhile,

*It will not be forgotten, in this connection, that the applicant has long before this demonstrated his moral and physical fitness for the position of engineer. Sometimes the physical examination is conducted by the machinery department, and at other times by the surgical department of the railroad. As will be noticed farther on, each applicant before being passed is examined with a view to ascertaining whether he is perfectly familiar with the time table, or not; also with the signals. The

makes of him a trustworthy engineer. This is what every fireman strives for and what his employer requires of him, for it is thus engineers are made.

If during the progress of the examinations candidates are unable to pass or answer the questions, it is generally thought well to extend the time a reasonable period.

If at the expiration of the time allotted the applicant is unable to pass, then the expediency of his seeking other employment naturally suggests itself, and this last for two reasons, as I have already intimated: First, that the service may not be clogged by men who cannot ultimately be promoted; and second, that applicants shall not be allowed to waste their time upon work not destined to be of lasting advantage to them. And in this connection it is not considered too much by those versed in such matters that applicants shall answer satisfactorily, both in writing and orally, eighty per cent of the questions asked them in each of the examinations.

And in regard to applicants, every assistance

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examinations in regard to these last are sometimes conducted by the machinery department, but more frequently, perhaps, by the operating department. Upon many lines, the superintendent is not satisfied until he personally ascertains that those taking charge of engines are familiar with the rules, familiar with the time table, and familiar with the signals. The machinery department looks especially to the technical fitness of those in charge of locomotives: the operating department requires in addition to this, perfect familiarity with the the rules governing the movement of engines and trains over the road.

possible is rendered them, as already intimated, and they are at liberty to go to master mechanics, foremen and others for information in regard to those things they do not fully understand.

It will be seen from the foregoing that in no sense will the course of study be forestalled by the questions that are propounded and the answers thereto that are contained herein. Both the questions and the answers applicants will find it useful to critically study, as students pursue their studies at universities; but they must not only know the correct answers to the various interrogatories (because every engineer must understand them), but must understand their purport, so that they can reply to each question in their own language and according to their understanding of it. They cannot use the answers embraced herein—these are intended to be merely instructive. They must frame answers for themselves. Thus it will be seen that, while the assistance this Manual affords will save them much inconvenience and many inquiries, it will not save them from the necessity of studying and framing an answer of their own to each inquiry that the examinations contain.

Parallel with the examinations, and along the same lines, it is a growing practice on many well managed railroads to maintain schools of instruction for the purpose of teaching train men, and particularly engineers and firemen, in regard to the construction, use and maintenance of the air-brake, steam-heating apparatus, use of gas and

electricity for lighting, and other implements of an intricate or scientific nature that are used on trains. The expense of this systematic course of instruction is more than offset by the increased efficiency of those thus instructed. The efforts of railway companies in this direction are everywhere actively seconded by their employes, as it adds to their usefulness and renders more certain their promotion, or if not promotion, then successful competition in the strife for place and its retention. Accurate and extended knowledge of their duties, aside from its present value, cannot, it is also apparent, but be of the greatest possible use to those who possess it, should they, through the cutting down of a force or otherwise, find it necessary to seek employment elsewhere.

The examination of firemen and engineers has been disregarded on many roads, but it needs little discernment to see that this state of affairs cannot continue always. Companies lacking this element of strength will not be able in the long run to make a showing as against companies whose force throughout has been carefully instructed in technical knowledge of the highest order in regard to their duties. The omissions and mistakes of the inefficient and the scandals they will create, to say nothing of the extra expense such men entail, will compel the companies employing them to adopt a more comprehensive plan of selection and instruction, first with a view of preventing inefficient men from entering their service, or in case they have such,

to weed them out as soon as possible in the event they prove to be incompetent. In making these examinations the railroads will only forestall the act of the state, for it is only a question of time, and a short time at that, when firemen and engineers will be compelled to go before a State Board for examination as to their fitness, the same as steamboat engineers are required to do, unless the railroad companies forestall such action by themselves making the examination.

The questions that it is proper to propound to applicants for the position of engineer are many and intricate. The answer to each question, it will be observed, is of a nature to familiarize the applicant with his work and to make him of greater present usefulness, to say nothing of the future. The sooner, therefore, the applicant familiarizes himself with his present and prospective duties the better for him and his employer. The quality of service that the fireman renders while fitting himself for promotion, also operates for or against him finally. His work during this period is compared with that of others, as is also the care and intelligence he exercises in the use of oil, fuel and other supplies.

The position of fireman, it is proper to say, is not only one exacting hard work, but considerable knowledge of detail, so that he has an opportunity to show fitness in this respect, which is all-important in the positions that he aspires to fill.

CHAPTER II.

DUTIES AND RESPONSIBILITIES OF ENGINEERS AND FIREMEN.

The examinations set forth in this book with what follows, prepared with a view to ascertaining the fitness of firemen to become engineers, treat of things that it is desirable engineers should know—should have at their fingers' ends—in order to fill their places to the best advantage. If they are not familiar with them they should lose no time in becoming so. They are primary in their nature.*

The vast resources at the engineer's disposal, the result of experience, while much of it may be particularized in print, much of it cannot be. The beginner does not possess this fund of information and it is not expected of him. He is,

*While we must believe that it is desirable that the engineer should not only understand his own duties perfectly, but those of the fireman as well, it is nevertheless true that this universality of knowledge is not possessed by all engineers. This renders manuals all the more necessary. One reason why engineers do not possess the knowledge in question is that methods change after they cease to be firemen; thus we will say, the kind of fuel may have changed, from wood to coal. Whatever the occasion of the lack of knowledge, the lack exists and is recognized by railroad companies and excused because unavoidable, but in so far as engineers are deficient in the knowledge of the duties of firemen, manuals that throw light on the duties of the fireman are not only of value to the latter but to the engineer as well.

however, expected to attain it as quickly as possible. If he is ambitious and adaptable he will soon acquire it. The time required will be dependent upon the thought that he gives the subject and his ability to learn. Nothing connected with his business will be too small to escape his observation; nothing too trifling if it affords him information; he will avail himself of the literature, however scant, that dwells upon his duties or that has any relation to the train service; he will observe and study the actions of those about him; question with untiring zeal, all from whom he can gain light. He will not be satisfied with the fact that he has been found worthy to have charge of an engine; he will not stop until he understands the anatomy of his machine and its working as the surgeon does that of his patient.

After his examinations he will go on with even greater zeal than before, because his ambition will by this time have led him to aspire to even higher things. For these and other reasons I have thought it well to supplement what I have said with other things that relate to the responsibilities of engineers, and that must be known to firemen in order to enable them to run an engine. What I add is not new nor especially ingenious. It is, however, useful to engineers and a help to others. I cannot claim to be more than the compiler and editor, for others before me have given it expression in one form or another. It is of the common sense kind, and

partakes, like all corporate regulations, of a practical nature. I shall try to avoid as much as possible repeating anything concerning the duties and responsibilities of engineers already given.*

With this explanation, I proceed to enumerate such things as occur to me at this time as forming a part of the subject.

To begin, then, it may be said of engineers, that amiability, quickness of perception, skill and promptness of action mark those of the highest attainments. The fireman who hopes to become a good engineer must possess similar characteristics.

It is also a characteristic of such engineers that they are stirred by an ambition to excel in every way.

While the fireman is the subordinate of the engineer, the latter should seek to further his advancement by teaching him everything connected with the construction, maintenance and operation of the locomotive that his time and capacity for learning permits of.

The fireman on his part should show his appreciation of the kindness and interest of the engineer by his industry, amiability and willingness to obey orders.

The engineer and fireman must work together, each recognizing his dependence upon the other, if the best results are to be attained.

*I shall, however, be only partially successful in this, but while there will be more or less going over ground already traversed, it will be in connection with new ideas and a fuller development of old ones.

In reference to details, it is becoming more and more the practice for the engineer to have charge of both injectors. This notwithstanding the efficiency of the fireman in this direction. If, however, the fireman miscalculates in regard to the requirements of the engine, and, in consequence, finds his fire too low, and the steam pressure dropping unduly because of it, he must call the engineer's attention to the fact, that the injector may be shut off and the supply of water reduced so that the pressure may be the more quickly regained.

Among many other things appertaining to engineers, the study of friction and the knowledge of what is dependent thereon is essential. Economical and effective use of oil cannot be attained without it.

Aside from information relative to more practical things, the engineer and fireman must know what clothing to wear, and the food best suited to their requirements.

They must study particularly the best methods of doing repair work: packing glands, cellars and boxes; removing brasses; keying rods; setting wedges, and work of a like nature about the engine and tender.

No one is qualified, it may be said, to operate an engine, who does not know in advance what to do in every emergency of train service. He must be able to act quickly and in the light of the best practices. In the cases of delays and mishaps, there is no time to study up questions

or situations. The man in charge must be able to act instantly. There are, in the generality of cases, preferred methods of procedure in the case of break-downs and other mishaps. With these the engineer should be familiar. He is also expected to be able to make such repairs on the road as are possible under the circumstances; to be able to temporarily adjust eccentrics or the front-end appliances, set wedges, and disconnect the engine; to be skillful in the treatment of hot journals or bearings, and have an ear so trained as to be able to detect and locate a blow or a pound that may cause a break-down.

The faculty of observation is to be cultivated by engineers and firemen. Some men, without apparent effort, are ever conscious of what is going on about them, while others see nothing. It is necessary that the defect of the latter should be corrected if they would become valuable in their places. Everyone ambitious of preferment should seek information from the better informed men about them, and should not be rebuffed or discouraged if replies to their questions are not always courteous or direct. Practice and reading will do the rest.

In the operation of railroads, men engaged for years on a particular class of engine, have been known to remain in ignorance of other classes about them. This may be remedied by study and observation. Certainly any engineer thus handicapped labors under great possible disadvantages.

It is a duty required of engineers, in many cases, that they shall reach the engine-house while their engine is over the pit, that they may thus be enabled to examine it from underneath, to better advantage. They are also expected to inspect the packing of truck cellars, see that the bolts and nuts are tight, look after the eccentrics and see that the oil holes are clear and oil cups filled. As the engineer is responsible for the fulfillment of the fireman's duties, he is also required to see that they are not neglected.

When the engineer does not know in advance the engine he is to run (that is, when the engines are pooled or worked in common), he must, upon taking charge, exercise greater care than he would otherwise, to see that it is provided with necessary tools, blocking and other appliances. He should also examine the work-book in such cases, to see what repairs were last reported as being necessary and what has actually been done. Parts that have been repaired always require more attention than others, because of the friction that intervenes in such cases. The inspection of the engine and tender by the engineer, it is apparent, is the first thing to be done on taking charge. The work should be systematic and thorough. In those instances where the roundhouse force looks after the packing of the driving boxes, tank boxes, truck cellars, and so on, the engineer must still see that the work has been done properly. Many engineers insist on doing it themselves, as they feel greater confi-

dence that they will get over the road promptly and without mishap than they would if the work was performed by an employe of the roundhouse.

Among the further duties of the engineer these may be briefly summarized: To see that the water supply in the boiler is ample — this he does by trying the gauge cocks and noting the indication in the water glass; to try the gauge cocks frequently when on the road, using the water glass as an auxiliary or indicator merely; to look from time to time into the fire-box for leaks, and if the engine has an arch, to see that it is in place; to inspect the air pump and its lubricator, the guides, guide bolts, crosshead and piston rod packing, bearings, rods and rod bolts, keys and set screws, wedges and wedge bolts; to see in filling oil cups that the amount of oil required indicates that there is no stoppage of the feed or oil hole; to examine the wheels and flanges for breaks, chips or cracks, and the driving wheel centers and tires to see that they are not working loose; to see that the sand pipes are open, that the headlight is filled and trimmed and the reflector cleaned, that the cinder hopper is tight and that no leaks appear in the front end; to blow out the steam heating pipes in winter lest they be clogged with ice; to ring the bell a sufficient length of time before starting to enable any one who may be working under or about the machine to escape;* to see before leaving the

*Numerous accidents to life and limb have resulted from a neglect to observe this precaution.

engine house that the cylinder cock is opened; to start the engine slowly and under no circumstances to slip the engine for the purpose of throwing the water out of the cylinders; in backing the engine to the train, to see that the lubricator is started and all parts of the engine working in good order; to lubricate all parts of the engine before starting a train; to place the reverse lever in starting in the "corner" and open the throttle slowly and carefully so as to avoid jerking the train or slipping the wheels; to be particular if the rails are slippery or the load requires it; to sand the track before the wheels begin to slip; to be careful not to "catch" the engine when slipping on sand, as it is a severe strain to the machinery, and pins and rods frequently break under such circumstances; to use in sanding the rail only so much sand as is necessary to keep the wheels from slipping, as a train pulls harder on a sanded rail; to see when headway is attained that the reverse lever is pulled back to prevent unnecessary waste of steam and undue disturbance of the fire by too strong a draft; in starting (and also at other times) to look back and exchange such signals with the rear end of the train as may be necessary to be assured that the train is intact and in proper working order; to use full opening of the throttle except where a simple engine can do the work required with less than one-fourth cut-off, in which latter event it is economical to leave the cut-off at one-fourth and regulate the steam by the

throttle;* to see that water is supplied the boilers in as nearly a continuous flow as possible, to see that the water is, so far as practicable, kept at a uniform height, not losing sight of the fact that water in the boiler at a high temperature (or indeed warm water in the tank) represents so much heat energy available when the normal capacity of the boiler is inadequate to supply the demand;† to remember that the time to favor an engine by reducing or entirely stopping the supply of water to the boiler is when moving rapidly towards an ascent or heavy grade;‡ to see, when approaching dangerous places, drawbridges, railroad crossings, interlocking switches, yards, etc., that the train is under such control that a stop may be made, if necessary, before reaching the

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*To illustrate: It would not be economical to use one-half to two-thirds cut-off and throttle the steam pressure when the work could be done with one-fourth or one-third cut-off with a full throttle opening, while one-eighth cut-off with full throttle is less economical than one-fourth throttled, due to increased cylinder condensation, where the temperature of the cylinder has too wide a range.

†The capacity of water for storing heat is great, and this fact should be taken advantage of. When it is not, engines will too often be found standing at stations or descending grades with light throttle, and with steam blowing off; or blowing off when the water in the tank is cold, or there is but half a glass of water in the boiler. At such times the injector should be at work or the surplus heat should be used to warm the water in the tank.

‡After speed has been reduced (even though the reverse lever has been dropped down), the engine is using a less amount of steam and the injector may then be started.

danger point;* to see, in stopping, that steam is shut off a sufficient distance to permit slowing down easily; to see that the link is hooked down to give the valves more travel and keep the valve seats in better condition.†

It is the duty of the engineer to see that the air brake is used with care, bearing in mind that it requires the nicest judgment and skill at all times to prevent mishap or jarring of the train. In the event the water in the boiler gets low (through failure of the pumps, or otherwise) the fire must be banked or drawn.‡ It may be necessary in some instances to detach an engine and proceed to the nearest station for water when the supply is exhausted. It can, however, sometimes be dipped from pools or streams along the track, or, in winter, snow may be shoveled into the tank and melted. Everything should be done in such cases that is consistent with safety to

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*The speed limit in such cases is usually placed at six miles an hour, or as fast as a man can walk a short distance.

†This will also prevent the raising of the valves by compression from the cylinders, and where there are no relief valves on the steam chest, it will partially prevent the drawing of the smoke and hot gases from the front end into the cylinder. With some engines, having very long eccentric blades, it is unsafe to hook the links down to the lowest point while running fast, as in such cases a broken eccentric strap might follow.

‡"Banking" a fire usually means covering it with fine coal, well wet down, but sometimes it is advisable to cover with ashes or sand, which will practically extinguish it. "Drawing" or "dumping" the fire means knocking it through the grates and extinguishing it entirely.

keep the engine alive, but it is considered highly discreditable to "burn" an engine.

If the engine is priming or foaming, the cause thereof must be ascertained and the necessary remedies applied.*

In the care of the locomotive it must be remembered, among other things, that water projected from the smoke stack injures the paint on both the engine and cars. It looks bad moreover. In summer, after filling the tank with cold water, the heater should be applied long enough to prevent the tank sweating. Failure to observe this simple precaution may greatly injure the paint on the tank.

An important duty of the engineer is to see that the safety valves are regulated according to the steam pressure allowed the engine. Many companies undertake to make periodical tests of safety valves, gauges and air governors independently of the engineer. It should be a duty of the latter, however, to order a special test made

* Priming is generally caused by keeping the boiler too full of water. This can, as a rule, be prevented. Foaming is due to foreign matter in the boiler and may be relieved by a surface cock, or a blow-off cock, with which most engines are supplied. If the water used is of poor quality, the tank may be cleansed by flushing at the water station. In cases of priming or foaming, the true water level can only be determined by shutting off the engine and letting the water supply in the boiler settle. This should be done frequently under such circumstances. From an economical standpoint, the effect of working water into the cylinders (aside from the liability of knocking out a cylinder head and cutting the valves) may be appreciated by remembering that a cubic inch of water (which is not expansive) will make one cubic foot of steam, which is expansive.

whenever he may have reason to believe there is anything defective therewith.

At water and coaling stations, the engineer should utilize the time to inspect the bearings and running gear of the engine and tender and supply needed lubrication.

It is a duty of engineers to carefully inspect their engines at terminals, and notify the official at the engine-house what work is required to fit them for economical and effective use. Hot bearings should also be reported so that they may be examined at the shop, and in the event another person is put in charge of the engine, that he may be notified of the same.

Returns giving an account of delays, overtime, accidents, and for other purposes, should be made and transmitted to the proper officer as soon after arrival at the terminal station as possible.

In order that there may be no unnecessary loss of time in communicating with engineers and firemen when off duty, their addresses should be left with the foremen of engine-houses, or other designated officials.

In closing these instructions, it will be proper to again call attention to the necessity of wise and economical use of tools and supplies. Engineers and firemen cannot hope to make satisfactory records otherwise. Questions affecting the use of tools and supplies grow more and more important every year because measures for ascertaining the care exercised are becoming more and more effective each year. The subject is therefore, it will be

seen, one of supreme importance to the employe as well as to the employer.*

*The foregoing account of the duties and responsibilities of Engineers and Firemen, while complete so far as it goes, is necessarily limited, but taken with the examinations (questions and answers) and other matters treated of in this book, together with other volumes of THE SCIENCE OF RAILWAYS Series relating to the mechanical department of railways, will be found to cover all salient matters relating to the duties of Engineers and Firemen.

CHAPTER III.

STEAM AND ITS APPLICATION TO THE LOCOMOTIVE.

Books and lengthy treatises have been written on the subject, but, stripped of padding and unnecessary words, there is very little to be said if we omit other matters relating to the locomotive, including that of the art of firing, which things I point out elsewhere. What I wish to say here, therefore, relates simply to the process of getting the locomotive under way.

The power that imparts motion to the locomotive is the expansive force of steam. This force, which has been known for thousands of years, was first utilized for purposes of carriage in the early part of the nineteenth century.

As stated elsewhere, steam is the vapor of water generated by heating water above the boiling point. Hence steam is water in a gaseous state and is colorless and imperceptible to the eye. Saturated steam is steam either in contact with the water from which it was generated or, if separated therefrom, is kept at the same temperature and pressure. Wet steam is steam not only saturated, but also holding in suspension unevaporated water in the form of minute drops; it holds this water in suspension mechanically, due either to the ebullition of the water from which it is generated or else from a rapid flow of steam from near the surface of the water, in a similar manner as the wind off a rough body of

water is noticed to carry drops of spray. Dry steam is the term usually used for saturated steam in distinction from wet steam. Superheated steam is steam removed from contact with water and heated above the temperature of the water from which it was generated; it is variously called steam-gas, surcharged steam, or anhydrous steam. Steam more closely resembles a perfect gas when superheated than in any other state, and it is for this reason that in the locomotive the attempt is made to superheat the steam. The boiler has a dome from which, and at quite a distance above the usual water level, reasonably dry steam is taken, passed through a pipe called the "dry pipe," and branching in the smoke-box or front end of the locomotive where the escaping hot gases have a tendency to superheat it, passes into the two cylinders in which its energy becomes useful.

In steam, as in other gases, there is a natural repulsion between its various particles, each particle trying to separate itself from the others, so that it will fill the receptacle in which it is placed, regardless of the quantity of steam or size of the vessel holding it. Its natural tendency is to expand and thus push out whatever resists expansion. If the steam is enclosed and superheated, therefore, as in the case of a locomotive boiler, the natural tendency of its particles to separate is intensified and we thus obtain, according to its quantity or volume, the steam pressure required.

The vapor seen escaping from a vessel of boiling water, or rolling in clouds from the exhaust pipe of a locomotive, is only a modification or

diluted agent of the mighty force that does so much of the world's work. This vapor is steam that is resolving itself back into water; the change or condensation which is visible is caused by its contact with the cold air. Real steam, as just stated, is an invisible gas, or, rather, a transparent fluid, really water changed into gas by the action of heat. Accordingly, to make the steam that an engine requires water must be boiled. To hasten this and to lessen the cost, the boiler is permeated with tubes, or flues, connecting with the fire-box, into which the flames therefrom are drawn, thus multiplying the heating surface and, in so far as this is done, hastening the boiling of the water and the generation of steam.* As the water is transformed into steam it rises into the dome, as will be seen by reference to the diagram of the locomotive. From there it is released by opening the throttle valve and is thence conveyed, through what is known as the dry pipe and steam pipes, through the steam chest, thence to the cylinders.

It is, as is well known, the expansive power of the steam operating through the mechanism of the cylinders that affords the propelling power of the locomotive.†

In order to utilize this power there is connected with the cylinders a steam box which is com-

*This as well as other matters relating to the construction and appliances of locomotives is illustrated and described elsewhere herein.

†For diagrams of the various cylinders and the action of the steam therein, see various cuts contained in this work, both of the simple and compound patterns.

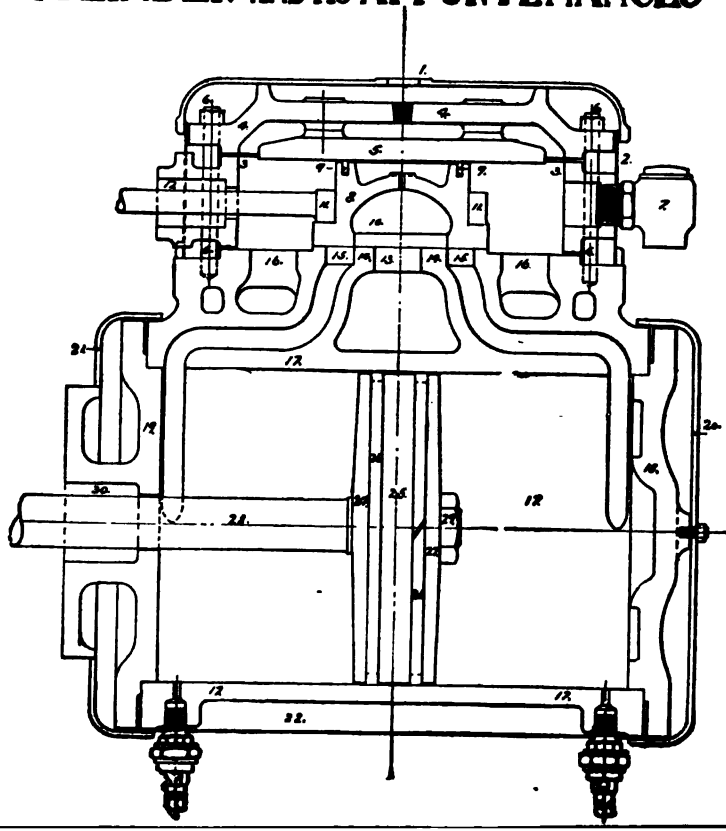
monly termed the steam chest, in which there is a slide valve, under which are three ports or openings, one leading to each end of the cylinder, and, the third leading to the atmosphere. The slide valve has a reciprocating movement whereby these ports are opened or closed. Motion to the valve is imparted by the revolving driving-wheel axles in various ways, the most common of which is by means of eccentrics and links with connections to the valve stems, as fully explained and illustrated elsewhere herein. The cylinder is fitted with a piston. This is movable back and forth from one end of the cylinder to the other. Thus the steam from the boiler is introduced through the steam chest into one end of the cylinder and forces the piston to the opposite end; then the valve opens the port at the other end of the steam chest and allows the steam to enter at the opposite end of the cylinder, and at the same time connecting the other side of the piston with the atmosphere, thus allowing the steam just used to escape; this reversal of pressure upon it forces the piston back to the place whence it first started. The escape to the atmosphere takes place through the smokestack in order to create a greater draught on the fire. This action back and forth, at first slow, is almost inconceivably rapid when the locomotive is under full headway. The piston described is in its turn, attached to a rod which works through a closely fitting opening in the back end of the cylinder. In this way the motion is carried outside of and beyond the cylinder. To the end

of the piston rod just referred to is attached the connecting rod which, in turn, is attached to the crank or revolving shaft of the driver. The backward and forward motion of the piston (called "reciprocating motion") is thus converted into a revolving or rotary motion. It is observed, however, that the connecting rod, when it has carried the crank backward or forward as far as it will go, loses its reciprocating motion and the piston will no longer produce a rotary motion. These positions of the crank are called its dead points. In the stationary engine this is overcome by a fly wheel, the momentum of which carries the crank past the dead points; then, too, stationary engines of one cylinder are not required to frequently stop and start with a load, as are locomotives. In the case of a locomotive the obstacle is obviated by having two cylinders with cranks, placed at right angles to each other and on the same axle; also, as the service demands the movement of the locomotive in either direction, backward or forward, the valve motion is so constructed that the engine is reversible.

It is thus that the steam is generated and its power applied.*

*I would in this connection refer the reader to the chapter on "Description of the Locomotive" in the volume relating to motive power.

CYLINDER AND ITS APPURTENANCES



1 Steam Chest Top Casing.
2 " " Side "
3 " Chest.
4 " " Cover.
5 " " Balance Plate.
6 " " Studs
7 " " Relief Valve.
8 Slide Valve.
9 " " Balance Stripes.
10 " " Exhaust Cavity.
11 " " Yoke.
12 " " Slow Stuffing Box.
13 Exhaust Port.
14 Bridge.
15 Steam Port.
16 Feed Port.
17 Cylinder.
18 " Head Front.
19 " " Back.
20 " " Casing Front.
21 " " " Back.
22 " Jacket.
23 " Casks.
24 Piston.
25 " Bull Ring.
26 " Packing Rings.
27 " Follower.
28 " Rod.
29 " " Nut.
30 " " Stuffing Box.

Fig. 1.

CHAPTER IV.

FIRING—COMBUSTION THE SOURCE OF ENERGY IN THE LOCOMOTIVE.

The fireman and his art are prime factors in locomotive running. No matter how well designed and perfectly constructed the engine may be, if the fuel is not manipulated according to scientific rules desired results will not be attained. It is not to be understood by this however that the fireman must be a chemist in order to be successful but it is certainly essential that he should know something about the fire he is tending so that he may treat it understandingly and be enabled to extract from every ounce of coal he throws on to it the energy that it should yield, thus reducing his own labor to the minimum and rendering the most efficient service possible to his employer. Moreover "a knowledge of the laws of combustion," says that practical writer Angus Sinclair, "teaches a man to go straight to the correct method and the information possessed enables him to deal intelligently with the numerous difficulties which are constantly arising owing to inferior fuel, obstructed draft due to various causes, and to viciously designed fire-boxes and smoke-boxes. The nature of fuel, the composition of the air that fans the fire, the character of the gases formed by the burning fuel and the proper proportion of air to fuel for producing the greatest degree of heat are the principal things to be

learned in the study of laws relating to combustion."

Combustion is the power which transports all trains on railroads, steamboats on the ocean, and turns 99 per cent of the wheels of commerce in all branches of trade. It is the most expensive of all powers for commercial purposes outside the power of vital action, and, in railroading, cuts the largest hole in the bill of expense.

Consider the large amount of money expended every year by railroad companies for coal, oil, and other fuels, and how much of this fuel may be wasted if the men whose duty it is to use it are careless and indifferent in its use. It has been estimated that when steam escapes at the safety valves the loss amounts to about one-fourth of a pound of coal each second or about a shovelful of coal per minute, or as an authority has graphically stated it, "It is the same or worse than throwing a shovelful of coal off the engine each minute."*

To get a proper understanding of the fuel economy question, many things must be considered.

First, a well-designed engine, properly adjusted draught appliances, with properly proportioned cylinders; second, a well-kept engine; third, prop-

*By an actual test on a locomotive at the Purdue University, it was found that, by blowing off steam through the safety valve for four consecutive minutes, six cubic feet of water, 336 pounds, was converted into steam and blown away, being at the rate of 84 pounds of water per minute, 1 2-5 pounds per second. In ordinary work, 6 pounds of water are converted into steam for each pound of coal consumed, and about 12 pounds per pound of crude oil. The amount of coal wasted in four minutes was 56 pounds, ¼ of a pound per second. In forty seconds, 10 pounds, or one shovelful of coal, would be wasted.

erly supplying the boiler with water and the fire with fuel; fourth, smooth, steady running; and last, but not least, unity of action between the engineer and fireman.

If an engine's cylinders are too large for the boiler, the boiler too large for the fire-box and heating surfaces, the draught appliances improperly adjusted, cylinders, valves, steam pipes, and joints blowing, valve motion out of order, it is next to impossible for any kind of engineer or fireman to make a good record with her. Two-thirds of a good coal record can always be traced to the engineer who by intelligence and interest in performing his duties accomplishes smooth, steady running. If the engineer takes no interest, the fireman will be compelled to take things as they are and may be blamed for the engineer's ignorance or carelessness.

There are two kinds of engineers, and two kinds of firemen; therefore, there are two ways of running and two ways of firing a locomotive. Some men would not make good, economical engineers with unlimited experience; some will try to make up all the time they are behind in the first two or three miles, or before they get out of the yard limits; some will leave on time, on a moderately fast run, and will run as fast as they can to the next town, but finding they are going to arrive too soon, shut off, regardless of the high steam pressure and big fire, and away goes the steam through the pop, repeating the process between every station. In this case the fireman through the conduct of the engineer has to fire the engine so that when leaving a town he will have a fire that will stand the conditions; he is determined to

keep her hot, if it takes all the coal in the coalpit; then, when the throttle is again shut off, the safety valve screams with joy.

Again an engineer may let the balance-packing blow, pistons and rods leak, steam pipes and joints leak, nozzles get loose or choke up, and so on, and should the fireman make suggestions as to the cause or cure, the engineer may tell him he is firing her too heavy, the first is full of holes, or something else; perhaps he will be informed he is not paid for running the engine, or he knows too much.

Such an engineer will be afraid to make a report, for he may not know what to report. His engine runs down and becomes a poor steamer, and will burn all the coal a fireman can shovel into the fire-box. Other engineers may have no confidence in themselves, or their engine's ability, and on a hill or heavy train will want her popping all the time, claiming they can not pull cars with cold water; or they may make a run for a hill like a boy running a mile to jump over a two-board fence, and are out of wind when they get there. The economical engineer is one who will do the right thing at the right time with the least possible amount of steam going through the cylinders, and has confidence in his engine's and his own ability, never gets in a hurry and is generally on time; he reads and keeps up with the times, and is not afraid to discuss questions with his fireman.

Fuel and Combustion. Coal is composed of several ingredients, as follows:—Carbon, oxygen, nitrogen, hydrogen, sulphur, ash or incombustible substances. In bituminous coal the proportions

vary as the coal varies, but, in good soft coal, are about as follows:—

Carbon, 50 per cent (gases); moisture, 35 per cent; ash, etc., 15 per cent.

Carbon forms the solid portion of the coal, and is the chief element in its composition. It is one of the most abundant elements in nature, and is found in various states or conditions, such as graphite, charcoal, the diamond, and so on. The difference between graphite and a diamond in appearance is as day to night, but, when analyzed, they are found to contain nothing but pure carbon.

In burning carbon, if the process of combustion is complete, it will give out 14,500 heat units. Next to carbon comes hydrogen, which exists only in a gaseous state. It is the lightest known substance in nature. Two atoms of hydrogen gas uniting with one atom of oxygen gas produces water, and, in the burning of a fire, forms the moisture which, together with the other gases, forms the gaseous substances in the coal. One pound of hydrogen gas yields 62,032 units of heat, and is the greatest heat known produced by the combustion of one pound of any known substance. The ashes, or incombustible matter in the fuel, come from the impurities contained in the vegetation from which the coal or fuel originated. Sulphur is one of the elements of coal, and is the chief element in the formation of clinkers. It exists only in a solid state.

Combustion, or fire, is the result of the rapid union of oxygen with carbon when uniting at a high degree of temperature, producing light and heat. It simply means decay in a rapid form. For example, take two pieces of wood, coal, or

any other substance that will burn, set one piece on fire; in a few minutes it is all consumed, leaving nothing but a few ashes. The other is thrown on the ground, and remains there to rot or decay; it may take years before the second piece is reduced to ashes, but the process is identical, and the heat units produced are exactly the same in both cases. The first we call fire; the second, decay. In reality, it is all decay, the first being the rapid process caused by the rapid union of oxygen with carbon, or fuel at a high degree of temperature. The second, the slow process of decay on account of the slow union of oxygen with the carbon or fuel, producing no light and no perceptible heat, but heat is produced just the same.

Combustion, as we understand it, is produced by the rapid union of oxygen with carbon, and is always accompanied by light and heat. It has been found upon examination that not only is the heat of combustion a fixed quantity whether the union of oxygen with carbon takes place slowly or rapidly, but that the heat evolved in any given chemical reaction is always the same, and is always accompanied by an evolution of heat.

Any substance which has the power to unite with other substances has power to do work and possess chemical energy; therefore all combustible material can do work. By uniting with oxygen, it produces heat, and the heat in turn is transformed into motion. Thus we see the source of power in the steam engine is chemical energy produced by the burning fire in the fire-box.

Where does this power or combustion or pent up energy come from, or how and where did it

originate? In ages gone by, no one knows how long, the rays or heat of the sun caused the trees and plants to grow and flourish in the atmosphere, which was abundantly supplied with carbonic acid gas; this acid or gas in the atmosphere entered into the growing trees and vegetation, and was stored there for man's use and benefit; as time went by, the vegetation, through the action of the elements, took a new form; just how or what was the cause is not known, but the result is coal.

The sunbeams building up the trees and plants expended a great amount of heat, and the heat expended equal to the amount of work done in producing the growth; the heat produced by one pound of coal is no more and no less than the amount of heat stored in the coal when in the form of growing vegetation. It absorbed the heat from the sun, consequently all motion produced by combustion through caloric or heat engines comes from the sun and planets. Having arrived at the source of power in all caloric engines, we will endeavor to utilize the power to the best of our ability.

One unit of heat equals 722 foot-pounds of work, or, to put it a little more clearly, will raise 722 pounds one foot high; 140,000 units of heat, which is the result of the perfect combustion of ten pounds of coal (one shovel full) will raise 772 pounds 100,000,000 feet high, or 100 tons 526 feet high; 33,000 pounds raised one foot high equals one horse power; 100 tons raised 526 feet equals 3, 187 H. P.*

*In practice it is impossible to obtain these results even with our best mechanical appliances, on account of the many

When a fire is lighted in a locomotive fire-box, the burning is slow at first, and shortly after the fire begins to burn, water is seen to ooze out of the cracks, and joints in the front end very often. Thus we say the front end is sweating; this is a mistake. Webster defines sweating as moisture issuing from the skin. This water we see coming out of the front end is the result of the process of combustion going on in the fire-box.*

Great care should be taken when starting a fire to prevent this formation of water in the front end, as it prevents the fire raising steam by stopping up the netting, thereby shutting off the draught and supply of air necessary for good combustion, and is also a source of much waste of fuel.

When steam has been raised, and the engine being prepared for the trip, care should be taken to have as much water in the boiler as it will hold without priming when the throttle is opened; in this a great amount of heat is stored; then, when starting out, it will not be necessary with the in-

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avenues of waste connected with the operation of a locomotive, such as unskilful running and firing, loss by radiation, condensation, loss of heat, loss by smoke and unconsumed gases, passing out of the smoke-stack as a result of imperfect combustion caused by bad or unskilful firing, poorly designed fire-boxes, and ash-pan appliances, and badly adjusted draught appliances, etc.

*When oxygen unites with the fuel and hydro-carbons at a certain degree of temperature, it produces hydrogen gas, one atom of hydrogen gas combining with one atom of oxygen produces water, and this water passes off from the fire in the form of vapor. This gaseous vapor passing along through the flues of the front end condenses as it comes in contact with the cold sheets of iron, forming little pools of water, which find their way out through the joints.

jector on, which would have to be the case with low water. The engine can run along for some distance before the injector is started thereby giving the fire a chance to burn good without crowding it. Care should also be taken to have a good fire in before starting, so that when the engine is working hard it will not be necessary to open the fire-box door, but the fireman can wait until the lever is cut back and a light exhaust acting on the fire; then, when the door is open, there will not be such a rush of cold air going in the fire-box through it.

In a fire-box one or two gases are being formed at all times during the process of combustion, and it is very essential that we know which of these two gases is being formed, as the formation of one is accompanied by great loss of fuel, while the other makes the hottest and most successful fire that can be produced by the burning of fuel in a locomotive fire-box.

When the fire is light and the proper amount of air is being admitted to it, so that one atom of carbon unites with two atoms of oxygen, the result of their union is carbonic acid gas. In burning carbonic acid gas, one pound of carbon yields 14,500 heat units. When this process is going on, the fire will have an incandescent appearance, and the inside of the fire-box will have a whitish gray color. When the fire is heavy or clogged by ashes or clinkers, so that the supply of air is restricted, and two atoms of oxygen are not present to unite with one atom of carbon, then one atom of oxygen will combine with one atom of carbon, and the result is carbonic oxide gas. In burning carbonic oxide gas, one pound of carbon

yields only 4,550 units of heat. In this case the fire will have a heavy, dull appearance, and the inside of the fire-box will have a black, sooty appearance, and heavy clouds of smoke will roll out of the smokestack.*

The practical duties of the fireman are to see that the grates and appurtenances of his engine are in proper order and that the full complement of tools is on hand before starting; that the flue sheets are cleaned of clinkers before his engine is fired up, and that the fire is evenly placed over the entire grate surface; that a bed of fire covers the forward portion of the grate next the flue sheets before the blower is used; that the blower be used as lightly as possible; that there is sufficient fuel on the fire before starting the locomotive to hold it and keep up steam while the engine is getting under way so as to permit the fireman to give his attention wholly to the signals and switches; that opening the fire door while the exhaust is strong should be avoided as much as possible; that coal is broken (if necessary) into pieces as near egg size as possible; that in firing under the "spreading" system the coal is broken into the proper size and scattered over the surface of the fire evenly, giving the sides and corners the preference.†

When the train is under way and normal pressure of steam has been attained two or three shovelfuls of coal should be placed in the fire-box

*T. J. Henderson.

†Coal broken into pieces of the proper size offers greater surface area to the heat and permits of being scattered more uniformly over the fire.

at a time, lightly and frequently and the door kept open only as long as may be absolutely necessary; the coal having been broken in advance, the shovel should be filled and drawn forward within reach ready for the coal to be placed on the fire —this before the fire-box door is opened.*

Except in very cold weather coal should be wetted to prevent dust and dirt. This gives increased weight to the fine particles which otherwise would be drawn directly into the flues causing not only waste of fuel, but stoppage of the flues.

If the locomotive is supplied with a smoke burner, it should be carefully looked after, and if there are any flues in the sides or rear of the fire-box for admitting air above the fire, they should be kept open, as it will tend to more perfect combustion and help to abate the smoke nuisance. Care should be taken not to throw the coal so that it will strike the flues or fall on top of the arch, if the engine has one.

A fire requires to be frequently replenished with small quantities of fuel in order to keep it bright. Heat is greatest when there is a rapid state of combustion. If there are clouds of smoke in the fire-box, heat will not readily penetrate them, and so poor results will be attained.

In case it is found necessary to maintain a

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*Another method of firing is known as the "banking" system used principally with certain grades of coal having few or no clinkers. In this case the coal is piled up at the back part of the fire-box, sloping down toward the front where the layer of coal being thin, is in a high state of incandescence—when the heap of coal at the back of the fire-box is thoroughly coked it is pushed forward and a fresh supply of fuel put in its place to undergo the same process.

very heavy fire in order to generate sufficient steam, it indicates that there is something wrong with the front end of the engine; either the nozzle is too small or may have become choked, or the draft appliances are not properly adjusted.

The temperature required to ignite carbon (of which coal is chiefly composed) is about eighteen hundred degrees. If, therefore, a large amount of coal is placed on the fire at one time, the temperature is reduced until the coal supplied can be brought up to the required temperature. The result is, first, contraction of the metal surrounding the fire-box, followed by expansion, thus subjecting the boiler to a great and unnecessary strain.

The importance of making proper use of the dampers is not always appreciated. With single part ash-pans, one damper, and that ordinarily the rear one, will be found most economical. By opening both dampers when the engine is working lightly with a thin fire, too much air will be admitted, and as air drawn through a fire in excess of the amount required for combustion tends to cool the gases below the point of ignition, waste of fuel results. Closing the dampers prevents the admission of air through the fire. This stops combustion and leaves the fire-box and flue sheets to gradually cool off. Opening wide the fire-box door will only partially prevent the draft through the fire, while it admits cold air directly onto the flues and sheets surrounding the fire-box, thereby cooling them so suddenly as to cause leaks.

In firing, the requirements of the service should be anticipated. A heavy fire should not be maintained when steam is to be shut off wholly or par-

tially. A hard pull, on the other hand, should be anticipated.

In starting, the coal should be well ignited so that there will be no occasion for opening the fire-box door until the train has gained considerable headway and the lever has been hooked up, with consequent lighter pull from the exhaust.

On approaching a stopping point, the dampers should be shut down, and if bituminous coal is used, but little, if any, fresh fuel supplied to the fire. If, however, fresh coal has been applied through misjudgment or otherwise, the blower should be opened and the fire-box door left slightly ajar to prevent smoke and injurious gases escaping.

Choking volumes of coal smoke and gases often find their way into passenger cars, causing great discomfort, when careless or unskillful firing is exercised.

It should be borne in mind, in approaching a stopping place, that a saving of fuel will result from letting the steam drop back a few pounds, rather than to allow it to escape through the safety valves. When it is found necessary to reduce the steam pressure, the dampers should be closed, rather than the fire-box door opened. The injector may also be started if the boiler is not already too full; if it is, the steam may, in many cases, be utilized by turning it into the tank to warm the water therein.*

The ash-pan and the front end should be cleaned

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*Practical experiment has demonstrated that every 11 degrees (Fahr.) increase in the temperature of the feed water produces about one per cent economy in the locomotive boiler.

whenever opportunity presents itself. A set rule cannot be laid down as to the frequency with which these duties should be performed. No great amount of labor will be required in cleaning the front end of cinders if the draft appliances are good and there are no steam leaks.

In regard to the ash-pan, it will fill up more or less quickly according to the grade of coal and the amount used. With a poor grade of coal, it may become necessary to clean the ash-pan on the road. The better steaming of the engine will more than compensate for time thus lost, and it may result that failure to perform this duty will necessitate the consumption of two or three additional tons of coal on a trip.

When sufficient air is not admitted through the body of the fire, there is a loss through the smoke-stack of about two-thirds, or more, of the heating properties of coal. This shows the importance of keeping as thin a fire as is consistent with the working of the engine.

Grates are to be shaken lightly as frequently as required.

If clinkers accumulate they should be removed at the first opportunity.

The steam pressure should be kept within the prescribed limits and not permitted to change rapidly either way.

The blower should be used while the injector is working, so as to prevent change of temperature of the boiler.

It is a truism that economical firing is impossible where the engine and injector are started simultaneously or both shut off at the same time on approaching stations. The cause of leaky boilers is

not necessarily the result of overworking the engine but is often due to poor management of the fire and injectors combined with injudicious use of the throttle.*

To prevent or stop the engine blowing off, the supply of water should be increased or the damper dropped.

If necessary to open the door of the fire-box while the engine is working, it is to be done slightly or swung open and shut.

So far as practicable the smoking or drumming of the engine while at stations, or when attached to or in the vicinity of a passenger train, is to be prevented.

Ash-pans and fires should not be cleaned near a bridge, culvert, depot, or building, or on a frog or switch, and the fire should be extinguished with water before leaving it.

At the close of a run, when the fire has been removed, the dampers and fire doors should be kept closed while the engine is being handled.

While it is possible for a man to become an adept without having studied the laws f combustion, it is nevertheless true that if he be thus skilled, he is obeying those laws. To such a one the study of combustion may be more interesting than beneficial, but to others study will open up an avenue to the knowledge they should possess if they would serve their employer acceptably. Men ignorant of the laws of combustion, who

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*In relation to the promotion of a fireman to the position of engineer, it is claimed by many experts that a fireman who has been out of freight service for several years should not be promoted to the position of engineer without again firing a freight engine for three or four months.

stumble into the right path, would attain it much easier and more quickly by study. All, therefore, should study the subject, and this both practically and scientifically.

Extended observation leads to the knowledge that lack of steam-making power in the engine is too often the result of over-firing. Especially is this true in the case of new firemen, or where the engine has a reputation of making steam poorly.

As already pointed out, perfect firing means the admission of fuel and air in exactly proper proportions, but as no fixed rule can be accurately followed, the fireman may hope to approximate it by watching closely the results of different methods of firing, remembering that, in many cases, by saving the shovelfuls of coal, the ton is sav d.*

The following are practical hints to firemen: If using soft coal do not carry over ten or twelve inches of fire in the center of the fire-box; keep the sides and corners a little higher; aim to fire in the corners and sides more than in the center. If the boiler will not steam well with a light fire, more air is probably needed at the front of the box. Leave the fire door open a little way for a

*While the foregoing instructions in regard to firing apply in the main to all classes of fuel, yet it is true they refer particularly, in several instances to bituminous coal. Where anthracite coal or wood is used therefore, modifications will be required according to the nature of the fuel and the class of fire-box and engine. However the general rule requiring that the fuel shall be so used as to burn most freely and create the maximum intensity of heat with the least fuel possible, applies in every case. This is also true in regard to keeping the grates free of clinkers and ashes.

few seconds after putting in coal, it helps to consume the smoke. Two shovelfuls is enough at one time if put on the bright spots. No boiler will steam well with the fire-box and flues full of smoke. If you have occasion to use the hook, be careful not to mix the green coal with that partly consumed. Do not use a slash bar if it can be avoided and be careful not to get green coal on the grates. If the box has an arch, keep a good space open between the arch and the fire. If the engine has a heavy train, it will need a heavier fire than with a light train and a fast run; always make calculations to fire according to train and speed. Hook out all clinkers from the fire as soon as you find them. Do not fire much while pumps or injectors are on full. If the engine has ash pan dampers use them when necessary. If there is more steam than is needed the dampers should be closed; a certain amount of air is necessary to make a fire burn as it should; if too much air is admitted the gases will be chilled; if too little they will not ignite; no rule can be made for the exact amount of air required, because different kinds of coal require varying quantities of air; only keep a bright fire low in the center of the box where the most air is needed and watch when the greatest flame appears in the fire-box with the least smoke going out of the stack; attend to the fire often, and do not use lumps of coal larger than an egg. Keep the ash-pan clean or the grates will burn out. If firing an engine hauling a passenger train, on approaching a station, as soon as the throttle is closed, put the blower on lightly and open the fire door about half an inch; when nearing the end of the trip let the

fire run low. Do all you can to help the engineer, but do nothing without first knowing that he wishes it done. Keep all tools and cans clean and be ready and willing to aid him. Try to learn what he does and how he does it, trying to anticipate his wishes.

The following illustrations show graphically the effect of different methods of firing:

Fig. 1 shows the system of heavy firing at the door, resulting in a light fire over only a portion of the grate surface as plainly shown by the path of the flame. This method of firing shuts off the proper supply of air to the back portion of the fire, with a consequent reduction in fire-box temperature, and forces the forward portion of the grate surface to perform the work that was intended to be distributed over the whole grate area.

Fig. 1.

Fig. 2 shows a system of light and level cross firing with slight building up around the edges, producing a bright fire with high temperature throughout the whole fire-box.

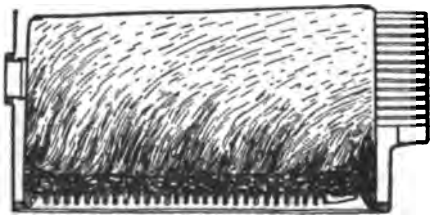


Fig. 2.

Fig. 3 shows good firing and the effect of a temporary reduction in fire-box temperature when a shovelful of coal is introduced.

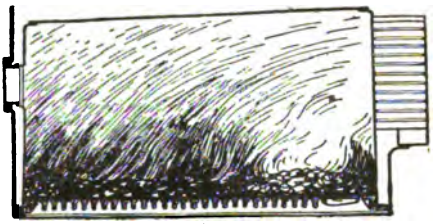


Fig. 3.

Fig. 4 shows the temperature in the front end of the fire-box restored at the time a shovelful is put into the back end as would be done with the system of cross firing, and a consequent reduction of temperature when the coal is put into the back end of fire-box.

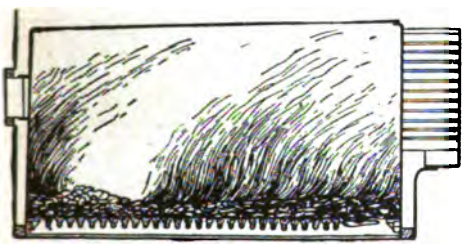


Fig. 4.

Fig. 5 shows an end view of the fire-box with a slight building up of the fire on the sides, as would be the result of the system of cross firing.

Fig. 5.

Fig. 6 shows an end view of the action of the draft in thinning the fire along the sheets of the fire-box unless the coal is introduced as per Fig. 5.

Fig. 7 shows the method known as cross firing. In this system a shovelful of coal is spread near one of the front corners (at 1), the next shovelful is put in the back and opposite side

Fig. 6.

(at 2), thus alternating the places where each shovelful is put between the corners and the middle of the grates, first on one side and then at the other. This method tends to keep the fire nearly level, except a little heavier next to the sheets to prevent too much air entering at these points, as the air will not be heated to the igniting point until it gets near the middle of the fire-box on account of the temperature near the sheets being held down by amount absorbed by the water on the opposite side of the sheets. It is claimed to be good practice to fire on one side or end, then at the other, in order that the bright fire in one place may help to burn the gases liberated from coal introduced at the other.

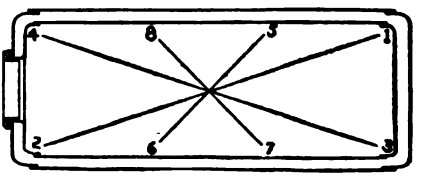
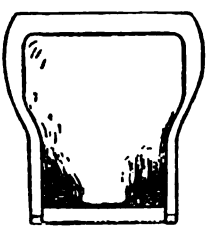


Fig. 7.



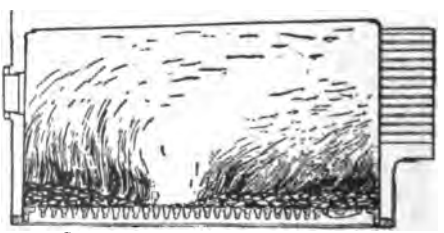


Fig. 8.

Fig. 8 shows the cooling effect from a hole being allowed to get in the fire, admitting a large volume of cold air into the fire-box.

CHAPTER V.

POINTERS FOR FIREMEN.*

When a young man enters the locomotive service his success depends on his own efforts. He should endeavor to reach the round house, if possible in ample time to get the engine ready for the trip, dust off the boiler head, sweep off the deck, and, if at night, have the cab lamps lighted, lubricators and oil cans filled and ready for use, wipe off the front window of the cab, if necessary, that the engineer may be able to see through the glass. If a night run, the cab lamps should be kept burning brightly so that the engineer can read the steam and air gauges correctly and tell the pressures. Engineers appreciate these little things and will very likely make it as pleasant for the fireman as they can and take an interest in him. When approaching stations where stops are made to oil, keep the coal out of the gang-way and if there is anything to do, such as a rod cup to fill or a truck to pack, anticipate the requirements and have the tools handy that the work may be done with as little delay as possible. Assist the engineer all you can and thereby obtain a more practical knowledge of the manner of doing the work. After you leave the station and the pressure is near the popping point, if the engineer's atten-

*The author is indebted for this eminently practical chapter, invaluable to firemen, to Mr. W. G. Wallace.

tion is taken up with something else, a jerk on the fire-door chain or opening the door will cause him to put on the injector at a time when you are ready for him. He will be quick to take advantage of this if he desires to save a little coal that would otherwise be wasted by allowing the engine to pop.

When doing switching, if you are pulling out over a switch with a string of cars and the signals are given on your side, when you get a signal to stop say to the engineer "that will do"; don't ride on the seat until the stop is made, but get down and drop in the amount of coal necessary and get back on the seat in time to get the signal to back up and transmit it to the engineer without delay. Brakemen, as a rule, are left-handed when doing switching, but there may be a train waiting for you to pull out of the yard and, of course, you want to get over the road. Getting signals promptly applies to all kinds of trains, but especially to passenger and way-freights. There is nothing that will spoil a train crew so quickly as to have them hustle to get their work done at a station and then have to wait from 20 to 40 seconds before the signal to go reaches the engine. If you receive the signals promptly you will soon make a record with the train crews. They will be glad to work with you, as well as to say, there is a man we never have to wait for when we give a signal.

Superintendents, traveling engineers and train masters ride these trains sometimes and observe these things. They also remember them in case you should get into trouble later on and should have occasion to go into their offices.

Firemen have been known in many instances

to have a good influence on engineers by sometimes taking more interest in their work than the engineer himself. Some engineers are not as attentive to their work as they might be at all times, but that kind of a man is usually a good fellow. When he finds that you are a worker and taking an interest in getting over the road he will try to help you, often a friendliness will spring up between you. If he should be a little careless with the injector and knock the steam back and you think you can improve on the pumping, ask him to let you try the left injector for a while to see how it works. If he does, you can perhaps give him an object lesson. The result will be that he will allow you to pump her if you can do better, or he may get the left injector changed to his side and pump her himself. It should not be the fireman's work to pump the engine, as a rule, but if he can do it better than the engineer he should be allowed to do so. But you do not want to think that this is putting work on you if you do have to pump the engine. It will give you practice and confidence in your ability when you are promoted. You all know that the good pumper that handles his water nicely is the best man to fire for, makes the best time, does less doubling on hills and earns more money for the company. Try and be that kind of a man when you go over to the right side. Your work is hard, but do not make it harder for yourself and others by growling about it. Sometimes you have hard trips and the engine will not steam properly. When you have a trip of this kind try and study the cause and fire the engine in different ways if you can. Sometimes dropping the front damper will help, or the back one, as the

case may be; see that the drop grate is up where it should be.

A fireman was noticed firing an engine with a mixture of fine and lump coal. He put the fine coal where it would burn on the grate surface back of the drop grate and the lump coal was thrown to the forward end of the box on the drop grate. When asked why he handled his fire in that manner he said "You know that I cannot shake my drop grate, and if I put the good coal up ahead that will not clinker as much as the fine coal. If the fire clinkers on the other grates I can shake them and break the clinker up." He had plenty of steam at the time and fire in nice shape, due to his intelligent method of handling the fire. Although the person who asked the question had years of experience on a locomotive he had never thought of that before. That fireman had his head working and it is needless to say that he was a good one.

It frequently happens that an engine is stopped near a telegraph office for orders and allowed to blow off, conductor and engineer in the office perhaps waiting for the "correct" or "O. K." from the train dispatcher, or to have the order repeated. Try and keep her cool. The operator can read the instrument better and will get the order that much quicker for you.

If the boiler is full of water to the working level, put the heater on and get the steam back into the feed water in the tender. You will keep down the noise and increase the temperature of the water. Feed water heaters are used in stationary practice. Must be something in it. This can be practiced when you get over the hard pull

and shut off to drift down hill, or at any time when the pop would open and the escaping steam be wasted.

A unit of heat is a quantity of heat that will raise the temperature of one pound of water one degree, and you can evaporate water from 90 degrees temperature with less coal than you could if your feed water was at a temperature of 60 or 70 degrees. One gallon of water weighs eight and one-third pounds. Figure it out for yourself. Try it sometime when you are on a hard steamer, for an experiment. It does not take long to put the heater in and you will save the heat that will come in handy when you are taking a run for the kill. You will, at least, keep the tank from sweating in warm weather, and that will add to the appearance of the engine. You may say that the injector will not work hot water. That may be true, but you can safely increase the temperature to the heat of a summer day. If you do, it ought to show up at the end of the month on the coal report.

Another thing that is often noticed, and is annoying, where bituminous coal is used, is the drumming noise made by an engine at times when standing at a station. It makes every window in the coaches rattle and some of the passengers shiver. This can be avoided by dropping a damper or opening the fire-door on the latch. Try it, and save the nerves of the nervous passenger or perhaps a sick friend of yours in the vicinity. This is caused by the hydrogen expelled from the coal combining in certain proportions with the oxygen present forming oxyhydrogen gas, an explosive compound, which, when subjected to a high tem-

perature, produces a series of minute explosions in the fire-box.

Try and keep your fire in its best possible condition by firing the best you can from the time you leave the terminal until you arrive. Avoid heavy firing and slugging. You will have less clinkers, get more air through your fire and have more steam.

Study the arrangement of the front end and adjustment of same. Note the results of certain changes. When you get an engine to run you will be able to report what you want done to make her above the average on the coal performance and not say on your report, "engine don't steam a little bit, fix her," and expect the man in the round house to know what to do to make her steam when he has had no chance to see how she burns her fire. The engineer that makes that kind of a report needs attention; he often has the front end changed when he should have the flues bored out, or steam pipe joints ground in, or valves and cylinder packing repaired.

As you study these things you will be able to determine the defect and it will not worry you so much, as you will know where the trouble is. If you have your fire in good condition when starting out, and put the coal in the fire-box as it is burned and when needed, with the engine handled properly, if she does not steam it is not your fault. Worrying over it will not raise the pressure and does no good.

As for the black smoke problem, fire your engine as light as you can and keep her hot. Have the blower on just before the throttle is closed. Use your dampers and fire door to avoid it all you

can. Conditions vary so that you cannot fire all kinds of engines and trains without some of it. Your officers are reasonable enough to allow for the difference between necessary black smoke and carelessly made black smoke. If you are careless and smother the town or the passengers, you may expect to hear from it. Sometimes this is more the fault of the engineer than the fireman. In order to have smokeless firing you must have a smokeless engineer. Without an engineer who will help you and work to that end you are up against a proposition that you should not be held responsible for. Right here is where harmony in the cab improves the service. There should also be harmony with the train crew. If the conductor stays too long at the register, or kills time visiting around stations being a good fellow, you may be safe in getting ready to make black smoke when you get the signal to go or lose some of your pressure. A slow conductor or train crew can make more black smoke and burn more coal than the best fireman can save or prevent.

If your engine is not equipped with an air or steam bell-ringer do not wait until the engineer whistles for a crossing and then get down to put in a fire to avoid ringing the bell. If you should strike something on a crossing you will have a hard enough time to prove that the bell was ringing. Be sure of it and get in the habit. It is a good thing on an engine to be sure.

Learn the time table signals and orders. You will be better able to fire your engine with economy. Sometime you may be able to prevent an accident by saying "they are not there yet" or, at least, you can select a good place to get off.

Many an accident has been prevented by fireman and brakeman knowing the orders.

All these little things go to make a good man for an engineer to have with him, with all due respect to the engineer. He may have never gotten by an order but he is liable to forget. It is only when they all forget that we hear about it. If a case of this kind should happen to you, treat it confidentially, and do not say "if it had not been for me there would have been an accident last night" at such a place. Keep that to yourself. That is one reason that they have two men in the cab, and it is part of your duty to assist in the safe and proper handling of trains.

Do your best.

ENGINE NOT STEAMING—WHY? ADJUSTMENT OF FRONT END ARRANGEMENT.

One of the first problems that would naturally appeal to a fireman, if the engine does not steam

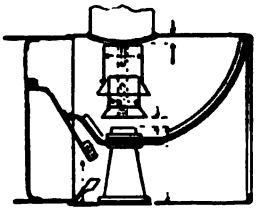


Fig. 1

properly, is to reason the cause. Figure 1 will serve to illustrate this. It does not matter whether the diaphragm is back or forward of the exhaust pipe, providing it is not set too close to the flue sheet at the top; if it is, the draft through the upper flues will be impaired.

In starting out with clean grates and flues, you should note if the fire is burning evenly on the grates; if not the diaphragm should be changed to equalize the draft through the flues and fire. Raising the diaphragm increases the draft through the upper flues and on the fire in the back of the box, and lowering it increases the draft through the bottom flues and the front end of the fire box. This is the purpose of the diaphragm and when you get it in position to burn the fire evenly on the grates you have done all that you can with it.

Now your engine may burn the fire evenly but does not make the steam, and you may want to make her sharper on her fire. You should first observe if the stack, exhaust pipe and nozzle are in line. A quick way to determine this is, to take a stick and stand on the boiler shell between the headlight and stack, or behind the stack, and hold the end of the stick over the inside, passing it around the top when the engine is working. If the exhaust steam strikes it harder on one side than the other you will know that the stack is not in line, or not filled by the exhaust steam, and the partial vacuum is not sufficient to produce the necessary draft on the fire. Of course you may observe this from the cab when the engine is working, and the stack may be filled sidewise and look all right and may not be filled front or back. If you try the stick method you will be sure of it. Sometimes engines have come from the builders with the stacks set back or ahead three inches. If it had been three inches out sidewise it would have been noticed very quickly. Now if we have our diaphragm adjusted properly, our stack in line

with the exhaust steam, and the engine is not sharp enough on her fire, raising the pipe or lowering the sleeve, or both, will increase her draft on the fire within certain limits. If then you do not get results the exhaust pipe from the air pump should be examined to see that it does not strike the flare on the pipe, or the steam pipes are leaking. If they are in good condition, as a last resort, you may have to decrease the size of the nozzle. But you should aim to run with as large a nozzle as possible, consistent with steam making, in order to reduce the back pressure in the cylinders. It is true that all engines will not steam

Fig. 2

alike, although they may have front end arrangements set the same. But if the flues are clean, and the stack and exhaust pipes are in line, you can use the adjustment of the best steamers as a guide to set the others by, and the changes necessary will be slight, providing the valve gear and cylinders are taking care of the steam after it is generated. A little study on this subject and the results obtained by the changes will make you familiar with the boiler and draft appliances.

To make this clear observe the figures 2 and 3. Figure 2 is over drawn for this purpose and is shown with a pipe and sleeve that extends from

the base of the stack to the base of the exhaust pipe, the dotted and broken lines representing the steam and gases passing to the stack. This is not a very large opening for the exhaust steam to expel the smoke and gases from the front end; and they are not thrown out, the vacuum is not formed and the air is not drawn through the grates to fill the vacuum in the front end. In

Fig. 3

Figure 3 we have the pipe raised above the nozzle tip and the sleeve lowered from the base of the stack so that the exhaust steam will expel the gases from the front end and a greater volume of air will flow through the grates and fire, promoting combustion. Consider that the nozzle, petticoat pipe, sleeve, and stack should do business in the front end the same as the tubes and the nozzle of the injector, and adjustments can be obtained that will be satisfactory. If the draft cannot be made strong enough in this manner then the nozzle should be bushed, but on account of the effect of the back pressure in the cylinders this should only be done when changing the pipe or sleeve will not produce it. If you have an engine without a petticoat or draft pipe, the nozzle tip should be as high as the center line of the boiler. If it is not an extension should be placed

between the tip and exhaust pipe to bring it up to the required height. Engines without petticoat pipes are improved by raising the nozzle tip to this height.

When the draft appliances have been adjusted to give the best results they should not be changed to remedy other defects, such as poor coal, bad weather, leaky flues, valves and cylinder packing blowing, poor pumping or manipulation of the throttle and reverse lever, or to shield a poor or indifferent fireman. It is very convenient for the engineman if he will make a sketch mentally or on paper of the adjustment of the front end. Know the size of nozzle, height of pipe above the nozzle tip, distance from sleeve to base of stack and height of diaphragm. Then if they are changed or become loose they can be replaced in their former position without guess work. This, of course, would apply only where men are assigned to engines regularly. If in pool service a similar record should be kept at the round house by the men having charge of the adjustment of same.

WHERE THE STEAM GOES AFTER IT IS GENERATED, AND HOW DISTRIBUTED.

Assuming that the adjustment of the draft appliances is such that the boiler is at its maximum efficiency, when the throttle valve is opened the steam enters the dry pipe and steam pipes and is admitted to the steam chest or chamber. Where the admission to and the exhaust from the cylinder is controlled by the valve, as it opens and closes the ports for the admission and exhaust of the steam. Fix this in your mind by cutting a

valve and seat out of cardboard or wood, or marking the valve seat, steam ports and exhaust port on paper and using the valve made of cardboard to move over the drawing. After you have

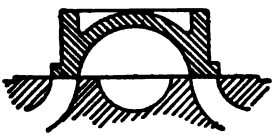


Fig. 4

made the drawing of the valve seat, cut your first valve to size as shown in Fig. 4 without lap. You will observe as you move this valve over the seat that as soon as one steam port is open for the admission of steam the other port is open to the exhaust cavity. This was the first form of the D slide valve, and steam followed the piston to the end of the stroke. In other words, each cylinder was filled with steam from the boiler twice every revolution. With a valve like this the eccentric was set at right angles to the pin.

Fig. 5

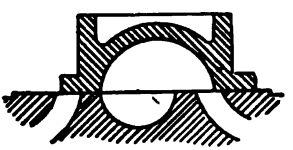


Fig. 6

One of the questions often asked is: "What is lap?" The answer is that it is the amount of valve that extends over the outside edges of the steam port when the valve is in the center of its seat. See Fig. 5. By cutting a valve as shown,

you will now see that in order to have the steam port open when the piston is at the beginning of its stroke, the valve must be moved to the position shown in Fig. 6 and given lead. Lead is the amount of opening of the steam port when the piston is at the beginning of its stroke. In order to get the valve in that position, you will have to change the position of the eccentric on the shaft. If the top and bottom rocker arms are of equal length, the large part of the eccentric should be moved toward the pin the amount of lap and the desired lead opening. With this valve having lap, the steam can be admitted to the cylinder for a portion of the stroke, when the valve closes the port or cuts off the steam. This is called the point of cut off.

Now if the cylinders in each of the above cases were of 24-inch stroke, by applying the valve with the lap and cutting off the steam at 12 inches, or when the piston had moved 12 inches from the end of its stroke, we would have the steam confined in the cylinder to push the piston to the end of its stroke by its expansive force, without filling the cylinder its full length with steam taken from the boiler, thereby using one-half the steam that we would with a valve like that shown in Fig. 4. The advantage of lap is that you can work steam expansively. By studying this out and in making the sketch of the valve and seat yourself, you will become familiar with construction of the valves and seats.

Observing the D valve, you will note that we have steam chest pressure on top of the valve, forcing it downward onto its seat. If the lip of the valve is covering the steam port or just closed

it, the steam in the cylinder is exerting a pressure upward or tending to lift the valve from its seat. We also have the pressure of the exhaust steam helping to lift the valve against the pressure of the live steam that is holding the valve down. The live steam being the greater, caused friction on the valve and seat, thereby using energy that absorbed some of the power of the engine. As the locomotive increased in size, higher pressures were carried, and larger ports and valves were necessary to admit and exhaust the steam to and from the cylinders. To reduce the friction between the valve and seat as much as possible, the back of the valve was relieved from the steam chest pressure by introducing a bal-

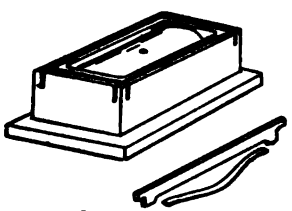


Fig. 7

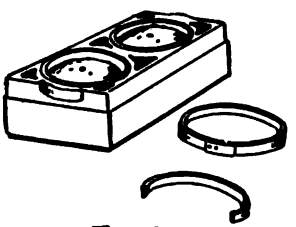


Fig. 8

anced valve and pressure plate, whereby a portion of the back of the valve was enclosed by strips or rings, preventing the steam from exerting a downward pressure on the part of the valve inside of the strips or rings. See Figs. 7 and 8. Holes were drilled through the back of the valve to the exhaust cavity to allow the steam that might leak past the strips or rings to escape to the exhaust passage and not accumulate a pressure on that part of the valve. The strips

are held up against the pressure plate by the tension of the springs under them, and the rings are held up by reason of being cut and the inside edge of the ring beveled to fit the beveled seat on the back of the valve, and the pressure on the outside of the ring has a tendency to force the ring tight to its beveled seat and fill in the space between the back of the valve and the pressure plate. If a spring or ring should break, the live steam would come inside the part of the valve that was enclosed by the strips or rings and escape to the exhaust passage through the holes in the back of the valve, causing a blow.

Which side is it that is blowing? We will determine that by placing the piston at half stroke on the side we wish to test. Open the throttle a little and move the lever from full gear forward to full gear backward, and repeat this operation on the other side of the engine. The side that is at half stroke, or with the pin on quarter, when the lever is the hardest to move from forward to backward motion, is usually the valve that has the broken spring or ring. By placing the engine on the quarter you get the greatest travel of the valve *in that position* when the lever is moved from front to back notch.

If we measure the area of the back of the valve in inches, then measure the area of the back of the valve that is inside of the balance strips or rings in inches, and divide the small area by the large one we have the per cent that the valve is said to be balanced. It is readily seen that you could not get a perfectly balanced valve of this style, as when working steam at a long cut-off the cylinders are filled with high pressure and the

pressure of the exhaust-steam coming in contact with the under side of the valve tends to lift the valve from its seat, causing a blow. This usually occurs when starting out of a station or when working hard. This may also be caused by the valve closing the port too early and preventing the exhaust steam from getting out, and the steam thus confined in the cylinder is compressed to a higher pressure than that in the steam chest, when the valve will be raised from its seat and steam will escape to the exhaust passage. Of course the valve can only lift until it comes up to the pressure plate, but that will be sufficient to cause a bad blow when a valve is overbalanced.

We will now fix five important things in our mind before we get to the piston valve.

(1) Steam entering the cylinder when the port is opened by the valve, is the admission.

(2) When the valve closes the port it is said to cut off the steam, or is known as cut-off.

(3) Steam thus confined in the cylinder, forcing the piston to the end of its stroke by its expansive force, is called expansion.

(4) When the steam port is opened to the exhaust passage it is called the exhaust.

(5) But as the steam has been expanded in volume it has a lower pressure, and the amount of steam that failed to get out before the port was closed to the exhaust passage is compressed by the piston on its return stroke and is called compression.

If an engine had excessive compression from any cause and the valve did not lift to relieve it, cylinder heads would be liable to be broken.

You will now observe that a piston valve can be

more evenly balanced than the slide valve. Some of them are made hollow so that the exhaust steam can escape through the valve to the exhaust passage at the other end of the cylinder as well as to the exhaust passage at the end of the cylinder it is coming from. See Fig. 9. As the piston valve is a neat fit in the valve chamber bushing, there is

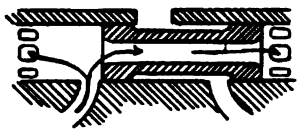


Fig. 9

no chance for it to lift to relieve compression in the cylinders and they are provided with relief valves or by-pass valves. If by-pass valves are used they are connected to the admission ports and the live steam chamber between the piston on each end of the valve. The valves are shown in Fig. 10 with one of the by-pass valves broken.

Each side of the engine has two exhausts every revolution and you remember that steam was ad-

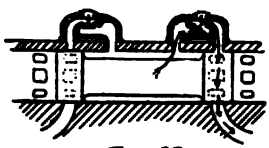


Fig. 10

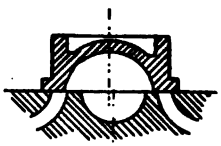


Fig. 11

mitted, then cut off and expanded until the piston had nearly reached the end of its stroke, and is then allowed to escape to the atmosphere through the exhaust port and stack. If the engine is lame,

note which side of the engine the piston is at the end of its stroke when the heavy exhaust occurs. That will indicate to you that there was too much steam admitted to one end of the cylinder and not enough at the other, and that the valve is traveling farther on one side of a line drawn through the center of the valve and the center of the seat (See Fig. 11) than it should, giving you a larger port opening to one end and not opening the port enough at the other end. This can be overcome and the engine made to sound square by lengthening or shortening the eccentric rod or rods to get the valve to travel the same distance each side of the line and give the same port opening for each end of the cylinder. If both exhausts on one side

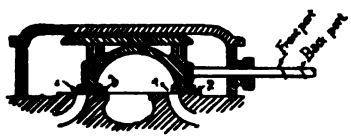


Fig. 12

are heavier than on the other, that would indicate that the valve on the heavy side is traveling farther than the one on the light side. To overcome this you can raise the box on the end of the tumbling shaft on the heavy side by placing shims between the box and frame, or lower the box on the other end of the tumbling shaft whichever is the most convenient. This is only advisable when there is slight difference in each side, as the trouble may be due to various causes, such as unequal length of link hangers, tumbling shaft arms sprung, engine low on one side, engine truck

spring broken, or loose bolt in eccentric trap allowing it to open. To illustrate the difference in the slide and piston valves we will refer to Fig. 12, which shows the slide valve with the front port slightly opened and the marks on the valve

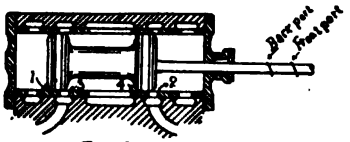


Fig. 13

rod made with a tram from a fixed point on the cylinder casting that indicate to the valve setter the position of the valve at all times, after the cover has been placed on the steam chest, in which 1 and 2 represent the admission edges of the valve, and 3 and 4 represent the exhaust edges. Fig. 13 represents a piston valve with inside or internal admission which changes the position of the edges of the valve, also the direction of its

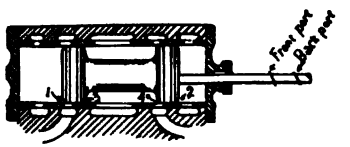


Fig 14

movement, which is directly opposite that of the slide or piston valve with outside admission, as shown in Figs. 12 and 14. It will be observed that the marks on the valve rod are also changed in their position. The inside edges of rings 3 and

4 are the admission edges of the valve and the outside edges of rings 1 and 2 are the exhaust edges of the valve. The valve in Fig. 13 could be given the same movement as in Figs. 12 and 14 by changing the position of the eccentrics on the shaft and still use the indirect rocker or motion. But it is usually more convenient to employ a rocker with the valve arm turned down opposite the link arm. This leaves the eccentrics in the same position as they were with the outside admission valve and indirect rocker, but gives a direct motion to the valve with internal admission as the valve rod and the eccentric rod are both traveling

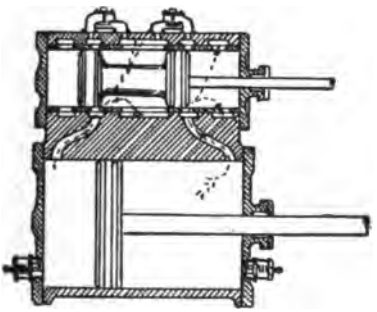


Fig. 15

in the same direction, then we have a direct motion valve gear for this style of piston valve. Fig. 15 shows a piston valve and cylinder, internal admission. The arrows indicate the passage of the steam. Fig. 16 shows a valve chamber bushing for a piston valve. The longitudinal strips or bridges are not to make separate ports as is sometimes inferred. Their purpose is to strengthen

the bushing and prevent the packing rings in the valve from springing past the edges of the ports while traveling over them. The bridges in the lower side of the bushing are wider than the others to insure sufficient bearing where the ends of the rings are held in place by dowels or stops that are placed in the packing ring groove in the valve to prevent the rings from turning.

As the piston valve can not lift from its seat as the D-valve can when compression is greater than the initial pressure, provision is made to relieve

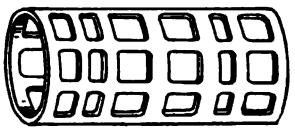


Fig. 16

the strain and prevent the fracture of cylinder heads by placing compression or relief valves in the cylinder heads adjusting the springs to the desired pressure. When the pressure exceeds the resistance of the spring the valve is unseated and the pressure relieved. Fig. 15 shows relief valves in cylinder heads, also a style of by-pass valve that opens when the compression exceeds the pressure that is admitted into the valve chamber between the pistons of the piston valve, when the compression opens the valve, instead of the steam escaping to the atmosphere it flows through the passage into the valve chamber and effects that much economy. Various styles of by-pass valves are used on piston valve simple and compound engines. By-pass and relief valves of adequate proportions are beginning to be appreciated on this class of power.

POSITION OF ECCENTRICS.
LAP AND LEAD.

The preceding has explained the functions of the valve; How to make the valve travel over the ports, admit and exhaust the steam from

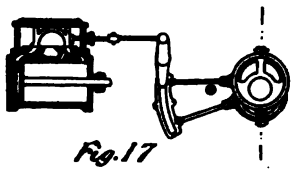


Fig.17

the cylinder is our next problem. Fig. 17 shows the position of eccentric with valve as shown in Fig. 4 with indirect rocker. When lap was added to edges of the valve the eccentrics were advanced toward the pin the amount of lap and lead desired to bring the valve in proper position to admit steam to the cylinder, when the rocker arms

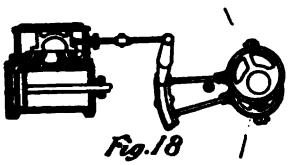


Fig.18

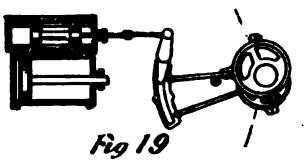


Fig 19

are of equal length, the advance of the eccentric on the shaft is equal to the lap and lead of the valve. See Fig. 18.

If the piston valve is used with outside admission, no change in eccentrics is necessary, Fig. 19. When the piston valve is used with inside admission the valve would have to move in the opposite

direction to open and close the port with this indirect rocker and the eccentrics would be changed to the position shown in Fig. 20.

Instead of being advanced toward the pin the amount of lap and lead they would be set at right

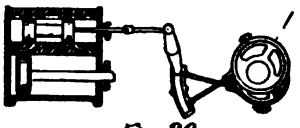


Fig. 20

angles to pin and advanced away from the pin the same distance, as is shown in Fig. 20; this is all indirect motion because the eccentric rod is traveling in one direction and the valve rod in the opposite direction. By a direct motion we mean that eccentric rod and valve rod are both moving in the same direction, as in Fig. 21. Fig. 22 shows an indirect and a direct rocker. Note that

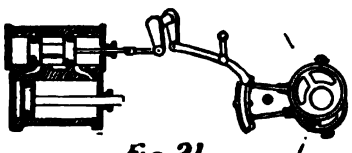


Fig. 21

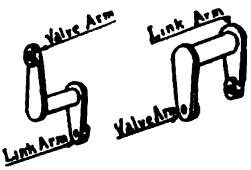


Fig. 22

the direct rocker has the valve arm turned down opposite the link arm and moves in the same direction, while the indirect rocker, link arm and valve arm move in opposite directions.

The foregoing diagrams show how the motion of the valve may be changed by placing the eccen-

trics on the shaft in relation to the pin or by the use of the direct rocker. With direct rocker, internal admission, the eccentrics are in the same position as with the indirect rocker and outside admission valve.

The marks shown on the valve rod or stem are simply to show the position of the valve after it is placed in the steam chest or valve chamber. With the slide valve the mark is usually made from a prick punch mark on the cylinder casting and scribed on the rod or stem when the valve is pushed up against a piece of tin placed in the steam port before the cover is put on the chest. With a piston valve the edge of the ring on the admission side is taken as the edge of the valve. Hence the difference in the marks for inside and outside admission piston valves. Note that they are reversed, usually plugs are tapped into the valve chamber so the edges of the rings of the valve can be seen when they are opposite the ports. When the plugs are removed, when setting valves or obtaining marks for this purpose, a few explanations are next in order. Lap is the amount of valve that extends over the edges of the steam ports when the valve is in the center of its seat and allows us to work steam expansively. Lead is the amount of opening of the steam port when the piston is at the beginning of its stroke and is increased as the lever is hooked up in the quadrant in proportion to the radius of the link. See Fig. 19 and note that the link block is moved farther away from the axle when it is near the middle of the link, than when at the ends. This shows how the lead is increased by hooking the engine up or working in a short cut off.

Inside lap of a valve would be the portion of the valve that extends over the inside edges of the steam ports when the valve is in the center of its seat, and delays the exhaust or prevents the steam from getting out of the cylinder, and would increase the compression or back pressure. Inside clearance of a valve is the amount of opening of the steam ports to the exhaust cavity, when the valve is on the center of its seat, and hastens the release or exhaust. When the valve is line and line it means that the inside or exhaust edges of the valve are in line with inside edges of the steam ports when the valve is in the center of its seat, just the same as the outside edges of the valve were line and line in Fig. 4.

Now the eccentrics are secured to the axle in a certain position in relation to the pin and move the valve in proportion to the throw of the eccentric and length of rocker arm, this gives what is termed the travel of the valve. If the valve travels farther on one side of a line drawn vertically through the center of the valve and its seat the travel should be adjusted by lengthening or shortening the eccentric rods, as the case may require, but the throw of the eccentric and its relation to the pin will remain the same until the position of the eccentric is changed on the shaft. If the lead is desired to be increased the eccentric must be moved in the direction to hasten the admission of steam to the cylinder, which will hasten all other functions of the valve accordingly. Remember that lead is the opening of the port when the piston is at the beginning of its stroke, and the opening of the port after the piston has commenced its stroke is the port opening. If the valve does not

open the port, when the piston is at the beginning of the stroke, the engine is said to be blind or set with negative lead, the amount that the valve extends over the edge of the port in that position. If the port was open 1-32 of an inch it would be termed 1-32 inch lead positive and if the valve edge extended over the edge of the port 1-32 of an inch she would be blind 1-32 inch or said to have 1-32 inch negative lead. No rule can be given to set valve on all classes of engines, as the lead varies in proportion to the radius of the link, and if the radius is a long one, the lead would not increase to the extent that it would with a short radius link; therefore, it is usually left to those in charge to set the valves to obtain the highest efficiency from the engine.

It is found that 5-32 to 3-16 lead opening in the running cut off, or where the engine does most of her work is a desirable motion if cutting off at 5, 6 or 7 inches of steam; but on the other hand, it has been demonstrated that an engine without lead is preferred for the reasons that the lead hastens the admission cut-off exhaust and compression and if the engine is on the center on one side the lead opening that she may have will retard the piston in completing its stroke and when at the end of the stroke will exert no rotative force to the crank until it has moved from the end of the stroke far enough to get the pin below or above the axle, and the exhaust will take place earlier on the other side or the side that is on the quarter, thereby losing the advantage of the steam behind the piston on one side and blocking ahead of the piston on the other, which condition will not increase the draw bar pull or tractive power of the engine.

Where practicable in freight service, engines should be set nearly the same in both motions and in passenger service it is advantageous to set each motion different, for instance: the forward motion may be set with lead or blind and the back motion line and line.

Various reasons have been advanced why valves should be set with lead but the tendency is to reduce it and in some instances to have the forward motion set blind or with negative lead from 1-16 to 7-32 inch, and the back motion line and line. A comparison of two engines of the same class set as above would be necessary to determine the merit of one over the other, but it is worth the expense of making the test.

The above is not written with a view of having the enginemen set the valves on the engines, but as a subject well worthy of their consideration and thorough understanding of the distribution and effective steam pressure.

Before leaving the subject of valves and eccentrics, it may be of interest to note that as the eccentric rod is brought opposite the link block, the more work is performed by that eccentric and the greater is the travel of the valve.

A word of explanation why the lever should not be placed in or near full gear, when throttle is closed at high speed. If we take a modern engine with a valve travel of 5½ inches, the valve will possibly weigh 150 pounds; a wheel 72 inches in diameter will make 280 revolutions per minute at a speed of 60 miles per hour. When the lever is in the corner the eccentric must push and pull the valve over its seat 280 times 5½ inches or over 128 feet per minute, in addition to stopping and

starting the valve 560 times per minute. By keeping the lever notched up where it feels easy when the throttle is closed the valve will not travel as far and the work will be divided on both eccentrics in proportion to the position of the link block in the link, and may prevent hot and broken eccentrics, broken valves and yokes and excessive wear on the valve gear. There will be time enough to get the lever down as the speed is reduced and the advantage gained is obvious.

RODS AND WEDGES.

With a boiler of steam generating capacity, and a valve motion that will distribute the steam properly when the lever is hooked down in starting the train, if there is lost motion in the rods and boxes, it develops into a pound that is annoying to the enginemen and detrimental to the machinery. In order to improve conditions we should first ascertain its location and apply the remedy. In keying the rods on an engine, if you will place her on the center on the side you wish to key, the other side will be on the quarter. Key all the rods on the center except the front end of the main rod. That should be keyed on the quarter. If you have an engine on the right forward center you can key the front end of the left main rod, then key all the rods on the right side, except the front end of the main rod. Move the engine to forward center on the left side and key the front end of the right main rod and all other rods on the left side in that position. Why? If the main pin is round it does not matter in what position the engine is placed to key the back end of the main rod, but

the tendency is for the pin to wear out of round, and if keyed on the center so it can be moved on the pin it will be keyed so it is loose on the largest part, therefore, it is readily seen that by keying the back end of the main rod and all side rods on the center you are keying so they will not pinch or seize the pin, and the front end of the main rod should be keyed on the quarter for the same reason. If the side rods are free when passing the dead centers you need not fear hot bearings on account of improper keying.

When the pin is on center and steam is admit-

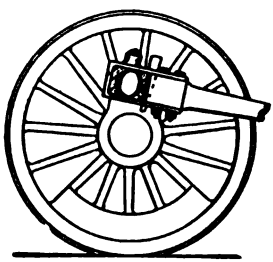


Fig. 23

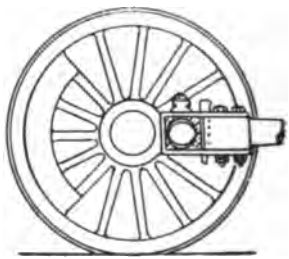


Fig. 24

ted to the cylinder, the pressure on the piston is exerted on the pin but does not exert any rotative force on the wheels until the pin is above or below the center line, the rotative force increasing from the center to the quarter and decreasing from the quarter to the center If the engine is always running in one direction, the pin will wear out of round on one side of the pin only, but if running in both directions the pin will wear on both sides and become oval. A good way to prove this is to make a mark on the pin and watch the rod push it

while the piston is making one stroke and pull it while making the other, but the pressure is on one side of the pin when running in either direction and is wearing that side only. See Fig. 23 showing small diameter when keyed on quarter. See Fig. 24 showing large diameter when keyed on center.

The reason for taking down the side rods on the opposite side, when one is broken, is apparent; also why the top guide wears most when the engine is running ahead.

The engineman that puts the engine on the quarter and has the fireman work the lever with steam in the cylinder while he drives down the key to take out the pound in the back end of a main rod is taking long chances on melting the babbitt or causing a pin to run hot, if the pin is not round.

Some Baldwin engines have the front end rod straps as shown in Fig. 25 and the strap bolt must be loosened to key up the brass. If you desire to

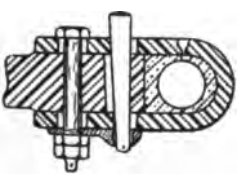


Fig. 25

key up an engine with this kind of a strap, loosen up the bolt before you try to key it, or make a report to have the front end of main rod brass filed. Engineers have often reported brasses filed because they did not understand how to key this kind of a rod.

By keeping up the wedges so the driving boxes will not pound, the rods will run longer without the brasses getting loose in the straps. If setting wedges up is a part of the engineer's duty, a very convenient method of setting them up without getting them too tight is to place the engine near the top quarter on the right side, the lever in forward motion, cut out the driver brake, and set tender

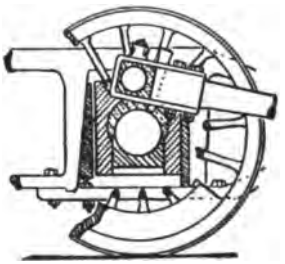


Fig. 26

brake or block the drivers, then by opening the throttle a little, steam will enter the back end of the cylinder and pull the crank pin ahead (see Fig. 26), thereby pulling the driving box up against the shoe and leaving a space between the back of the box and jaw free to push up the wedge. Loosen the wedge bolt and with a small bar as a lever on the binder or pedestal braces, push up the wedge until it has filled the space between the box and the jaw. Tighten up the wedge bolts and move the engine ahead one-fourth of a revolution and repeat the operation on the left side. Simple, isn't it? The reason that the top quarter is specified is because the work may be done without getting under the engine and the counter balance will

not interfere with getting at the wedge bolts. Before setting up the wedges it is advisable to have the binder bolts tight, as the loose binder bolt will often cause a pound of the box same as a loose wedge.

LUBRICATORS, PRINCIPLE OF WORKING AND DEFECTS.

It is good practice to oil the engine systematically before leaving a terminal. But before taking up the subject of lubrication let us familiarize ourselves with the construction, operation and defects of the lubricator and briefly consider the principle on which it works.

If we take the ordinary lubricator and cut it in two, we have it as shown in Fig. 27. When filled with oil and the filling plug screwed to its seat and water valve closed at the back of the cup, there is no opening for the oil to get out of the oil reservoir only through the pipe leading to the sight-feed glass past the regulating valves, and we have no pressure to force the oil out until the water valve is opened. The water from the condensing chamber flows past the water valve down the pipe to the bottom of the cup. The oil being the lighter, floats on the water and flows into the pipe leading to the sight-feed glass as fast as the openings at the regulating valves would relieve the oil, and the water being supplied by the steam condensing in the chamber above the cup and flowing into the oil reservoir as fast as the oil is fed out.

The small pocket at the end of the pipe leading from the condensing chamber is to prevent the water from being all drawn out of the cup when it is drained before refilling, and also to keep the oil

from backing up in the pipe when the cup is being filled, as the oil floats on the water in this pocket. The pocket directly above it is for the purpose of providing an air chamber by trapping the air that is above the oil when the oil level comes in contact

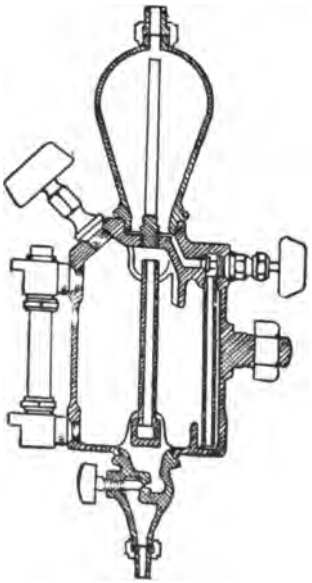


Fig. 27

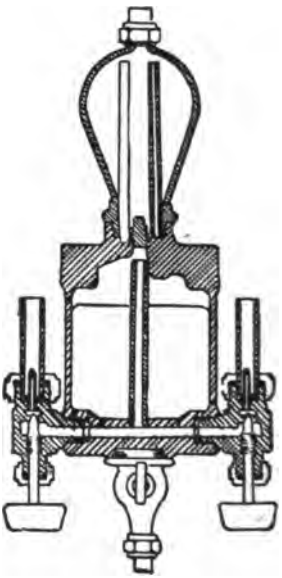


Fig. 28

with the lower edge of the partition, when the cup is being filled.

This makes an air or expansion chamber and prevents damage to the lubricator when it is filled with cold oil and left with the valves closed. The oil expanding, as it becomes warm, might bulge or break the cup if there was no provision made for the expansion.

Now, if we had a lubricator, as shown in Fig. 28 opening the steam valve on the connection at the condensing chamber and the water valve, we would have a pressure to force the oil out of the cup equal to the steam pressure and the weight of the water in the condenser above the level of the oil in the cup, which would allow the oil to flow out of the feed valve nipples in a stream as soon as

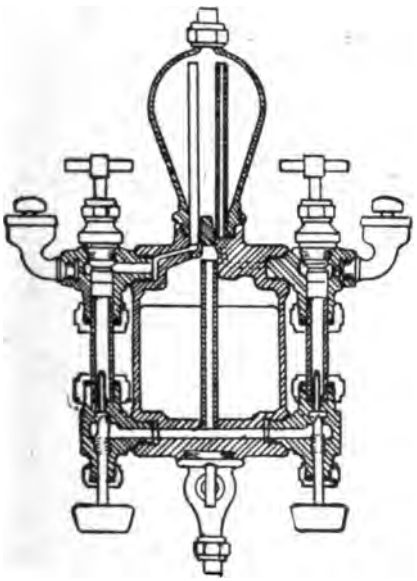


Fig.29

there was the least opening at the regulating valves. This is similar to the conditions when the lubricator has an enlarged choke plug or an equalizing tube stopped up.

In order to complete the illustration, we now refer to Fig. 29 and find that the pipes that lead from the condensing chamber to the small chambers at the top of the sight-feed glasses and the connection to the oil pipe is obstructed by a plug

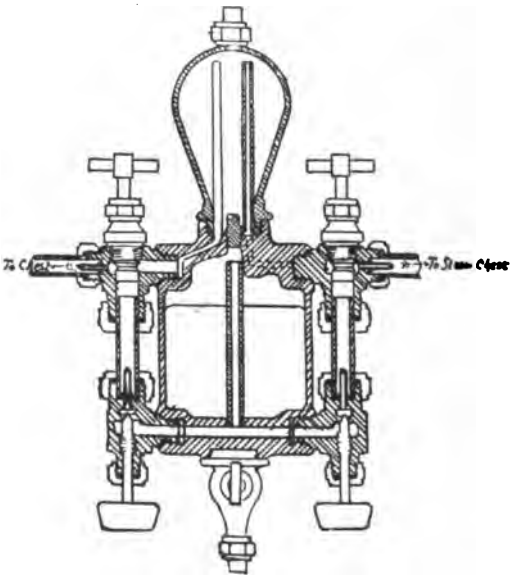


Fig.30

or choker (see Fig. 30) with a very small hole in it. This plug is to prevent the steam that flows from the condenser through the pipe or equalizing tube to the chamber above the sight-feed glasses from escaping too rapidly.

The choke plug, or choker, only allows a small jet of steam to escape and the pressure in the

lubricator is equalized. Therefore, we have the difference in the pressure equal to the head of water in the condenser to force the oil through the sight-feed nipples. This difference in pressure and the buoyancy of the oil causes the oil to rise through the water in the sight-feed glasses and chamber at the top of same to the level of the water which is as high as the hole in the choke plug.

The steam from the condensing chamber flowing through the equalizing tube and choke plug carries the oil to the oil pipe and forces it to the steam chest as long as the pressure at the lubricator end of the pipe is the greatest. This is the principle on which the sight-feed lubricator works and the action is practically the same with the equalizing tubes on the outside or inside of the condensing chamber.

Now, if we fill our lubricator and open the steam valve to the condensing chamber wide open, the steam will flow into the condensing chamber and equalizing tubes. The steam around the outside of the tubes will condense until the water rises to the top of the pipe and the steam that has passed down the tubes will condense and fill the sight-feed glasses and chambers above them with water, level with the hole in the choke plugs. The small jet of steam that flows through the opening in the choke plug will carry the water produced from the condensation to the oil pipe.

Now, if we open the water valve wide, the water from the condensing chamber will flow into the oil reservoir and force the oil to the top and into the pipes leading to the chambers under the sight-feed glasses. The regulating valves are for

the purpose of adjusting the openings in the nipples to allow the oil to feed up through the water in the sight-feed glasses fast enough to meet the requirements or the service.

If we find that the oil is feeding very much faster through one of the sight-feeds than the other with the same opening at the regulating valves the reason for it must be that there is less pressure in the chamber above that glass, due very likely to the equalizing tube on that side being partly stopped up or the hole in the choke plug worn so large that the steam from the equalizing tube would not maintain an equal pressure on the water in the glass and chamber above it. If the choke plug was loose or missing, the same results would be obtained. But it is clear that the trouble is in that part of the lubricator.

Should the oil escape out of the cup in any other manner than through the sight-feed glasses, the trouble would very likely be found in the partition that separates the condenser from the oil reservoir, or a sand hole leading into the water passage above or below the water valve, or the plug above the pipe leaking. If such is the case, the oil would rise to the top of the water in the condensing chamber and flow through the equalizing tubes, through the chokers to the oil pipes leading to the steam chests. This would cause the loss of oil and its disappearance would be noticeable only by the observance of the oil gauge glass.

When this defect exists, and you fill the lubricator several hours before you go out, if the oil is all gone when you come to the engine, do not think that some one has drained your lubricator to make

an oil record. Better have it tested and the defect remedied.

If the lubricator feeds for a short time after being filled and then water flows up through the glass instead of oil, this defect is due to a hole in the oil pipe leading to the chamber under the nipple, or a loose pipe, and oil is fed until the displacement of oil in the reservoir allows the water to come up to the opening in the pipe, when the water is fed through the glass. The only thing to do in this case is to use the auxiliary oilers, or drain the cup partly and refill with oil, which will last until the water again raises to the defect in the passage or pipe. Have it repaired when you get in.

If the choke plug becomes stopped up, it can usually be blown out by closing the steam valve on the lubricator, opening the drain cock and then opening the throttle. The steam from the steam chest will flow up through the pipe and blow the obstruction out of the plug. If the nipple above a sight-feed regulating valve is stopped up, close all other regulating valves and water valve. Leave the regulating valve, that will not feed, open. Open the drain cock and steam will flow from the condensing chamber through the equalizing tube, forcing the water in the glass down through the nipple past the regulating valve, thereby removing the obstruction. It is best to always open the steam valve first and close it last; the water in the glasses will remain clearer and less trouble will be experienced with the lubricator.

When the cup becomes warmed up, keep the steam and water valve wide open and see that the steam pipe from the boiler to lubricator connec-

tions is as large as the specifications call for, and that oil pipes leading to the steam chest connections have no abrupt bends that will choke the opening in the pipe or form pockets for oil or water.

LUBRICATING VALVES AND CYLINDERS.

Valve oil has a fire test of 600 degrees and should never be used as a lubricant on a cold bearing as the bearing will have to be warmed before the oil will feed. It should, therefore, be used only for where it was originally intended, valves, cylinders, and air pumps. To get the best results we should know the amount necessary to properly lubricate the parts. This is the point where the enginemen and the mechanical officers sometimes differ in opinion and where confidence in judgment is to be displayed.

One pint of valve oil contains about 6,600 drops when fed through a lubricator. Five drops per minute fed to each cylinder and one drop per minute to the air pump usually ought to properly lubricate them. At this rate a pint of valve oil would last about ten hours. There are a great number of engines that are able to be run on less very successfully, while on some of the heavier engines or compounds it may be necessary to increase that amount.

Is it not reasonable to suppose that the oil supplied to the valve seats and cylinders of a locomotive above the amount that adheres to the valve seats, cylinder walls and packing ring is thrown out of the stack and serves to clog up the exhaust pipes and is of no value as a lubricant?

With a high steam chest pressure, steam con-

denses in the oil pipe and the pressure from the lubricator does not always force the oil into the steam chest as it goes up through the sight-feed glass drop by drop, but the oil is held in suspension with the water in the oil pipe until the steam chest pressure is reduced, when the pressure from the lubricator forces it to the surfaces it is intended to lubricate.

Some enginemen, making long runs without shutting off steam or when the valves begin to get dry, ease off on the throttle to reduce the steam chest pressure and allow the oil to go to the valve seat. It takes but an instant and, more frequently, time is gained rather than lost by doing so. Try it and satisfy yourself if it is a good practice. When the throttle is wide open and the valve travel is short, the steam port openings are not sufficient to cause fluctuations in the steam chest pressure and the oil is held in the oil pipes, but when the throttle is partly closed the pressure in the steam chest is less than the lubricator pressure and the oil is forced into the chest.

In oiling the other parts of the engine the rod oil cups should be filled with clean oil and care should be taken to keep the spout of the oil can clean while doing so. If the spout of the can is used to stir up the waste on the top of the driving box, or to scrape dirt from an oil hole, and is then introduced to the rod cup there is liability of grit or foreign matter getting into the cup that will stop the feed and cause trouble from hot pins. The cups should be filled before leaving the terminal or at least looked at so as to know that they will not feed out before reaching the end of the

trip, and should be adjusted to feed as near uniformly as possible without throwing the oil all over the rods. The greatest difficutly is to get the feed regulated fine enough and still have it positive. A pin will run with very little oil if the

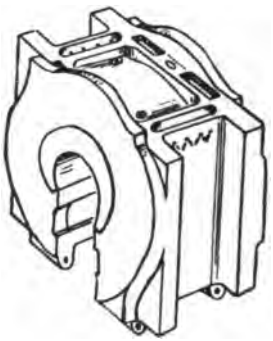


Fig. 31

feed is only constant. Get the feed set as fine as you can and run the pin cool. The same rule applies to the guide cups.

Starting in with a system of oiling and assuming that the lubricator and rod cups are filled, if convenient place the engine on the forward center with the lever in the back notch. This will make it easy to get the oil to the wedges and driving boxes on that side and the greater part of the valve gear on both sides. Commence at the back driving box and bring the spout of the can around the face of the wedge with a streak of oil. If the box is made as shown in Fig. 31 drop a little in the oil pocket that leads to the face of the wedge; put a sufficient amount in the center

pocket that leads to the journal, and treat the shoe and oil pocket on the front side of the box in the same manner, being careful to put the oil intended for lubricating the journal well over in the box as the cinders from the ash pit will accumulate around the axle on that side. As there is nothing to hold the oil in or keep the dirt out this is usually the side of the box that i first to get dry and then hot. The wheel center hub on the outside of the box will prevent the dirt from getting in on that side and also serves to help retain the oil. It is a little more trouble to get farther in with the oil can but it pays.

Be reasonably liberal with the amount on your first oiling as your time may be short at your next oiling place and, by giving a good oiling on the start, you will not need to do so much oiling afterwards. Now go to the next box, treat it as you did the back one, oil the eccentrics, tumbling shaft, rocker boxes, links, hangers, and all other connections to the valve motion, set the feeds on the guide cups but do not fill them full so the oil will slop out; two-thirds or three-fourths will run them all right and it will look better than to have the top of the guide bars covered with oil. If the bottom guide looks dry, make a streak of oil crosswise and that will lubricate it as well as if you made the map of a small river running the length of the guide. The cross head will push the surplus oil up to the end of its travel and benefit will be derived only from the amount that adhered to the surface. If you are running ahead the bottom guide will require but very little oil at any time.

Now give the engine trucks attention and go to

the other side of the engine oiling back to the front driving box, including the valve gear on that side. Then move her ahead one-fourth of a revolution and leave the lever in forward notch. Oil the boxes and eccentrics on that side the same as the other. If it was impossible to oil all the valve gear when the lever was in back motion it can now be reached with the lever in the forward motion, for instance, the lower end of the link on some classes of engines. The engine has now re-

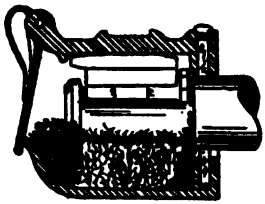


Fig. 52

ceived a thorough and systematic oiling. The fireman no doubt will appreciate the can being wiped off before it is placed on the shelf.

If the tender trucks need attention, do not use up a can of oil if the waste is oily. A packing iron pushed into the box clear to the back end and then given a rolling motion away from the journal will bring the oily waste at the bottom of the box up to the journal and there will be oil enough in it to run some time longer and still lubricate the journal.

At any time it is necessary to pack a journal box, first twist up a bunch of waste and push it hard against the back of the box; this to serve as a retainer to the oil and assist as a dust guard.

Then place the packing under the journal, as shown in Fig. 32, with a sufficient amount of packing in front of the journal to fill the space and keep the waste from working out. The sponging or packing under the journal should not extend above the center of the axle on the sides of the box or outside of collar on the end of the journal. The bunch of waste placed at the end of the journal simply serves as a block to keep the packing in place and should have no thread contact with the packing. Thus it serves the purpose of preventing the waste from being crowded out of the box by the collar when it is working endwise.

This method has been found very satisfactory and the boxes will run cool.

The sponging or packing in the boxes is for the purpose of bringing the oil up to the journals. See that it is kept in contact with them.

CARRYING WATER IN BOILERS.—EFFECT OF TOO MUCH OF A GOOD THING.—SPEED.

Men who have been accustomed to small power and low pressure have found some difficulty in getting into the habit of keeping the water level down to insure dry steam being admitted to the cylinders with the modern high pressure engine, for the reason that with the old style boiler the dome was placed well back on the boiler over the fire box and the throttle being opened had a tendency to raise the water in the glass above its true level in the boiler when the engine was working steam. Figs. 33 and 34 show this style of boiler at work and at rest, while Figs. 35 and 36 show a boiler of modern type with the throttle

open and closed. The dome being placed forward of the fire box and the steam and water at the higher pressure being more elastic. When the throttle is opened it forms a current of pressure

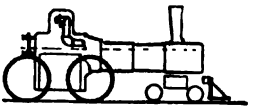


Fig. 33

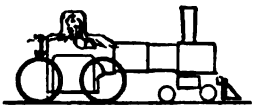


Fig. 34

and tends more to lower the water in the glass than to raise it. If the water is carried as high in both of the boilers when the engines are work-

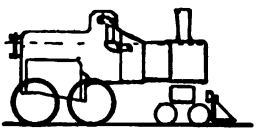


Fig. 35

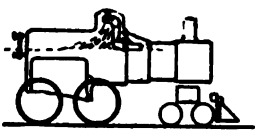


Fig. 36

ing, water will pass out with the steam and the efficiency of the engine is reduced. More water and coal will be consumed in performing the same amount of work than if dry steam was used.

The reason why valves get dry in some cases is also apparent. The old saying that you could burn the boiler but could not drown it is out of date. The time is fast now and the steam must be dry in order to make it. The question of working the engine with or without a wide open throttle and a long or short cut-off should be determined by the engineman, who should regulate them to the positions to obtain the best results. When the summit or the top of a hill is reached, if the

descending grade is several miles in length, keep your speed within the limits of the engine, and when the level is reached you will be in better shape to go right along. It is advisable to crack the joint on the throttle open when drifting down a long hill on either a simple or a compound engine, as it prevents the gases and cinders from getting into the cylinders, keeps the circulation up in the boiler and the fire in better shape. It is not necessary to use much steam to do this; enough to hold the relief valves shut is all that is required. Time can be made without falling down the hill on freight trains even if the engine will stand the speed.

In summer there may be some of the boxes in the car trucks that are not in as good a condition as the others, or in winter the oil may not get to the journal before the box gets hot, and if the excessive rate of speed down the hill changes the occupation of the brakeman to that of a car repairer time would have been made by descending the hill at a slower speed. Use your best judgment in the question of speed.

BALDWIN LOCOMOTIVE WORKS. RULES AND DATA. TRACTIVE POWER.—HOW TO FIGURE WHAT WILL SHE PULL.

With the engine adjusted to steam freely, a valve motion that will insure a good steam distribution and the machine properly lubricated, the next problem is the capacity of the engine to move tons of freight or passenger trains over the road. It costs money to operate a railroad and the revenue is obtained from the sale of transpor-

tation. Assuming that the locomotive is of modern design and assigned to the class of service best adapted to it, the next point to determine is the draw bar pull or how much tractive power will be developed to overcome the train resistance. First the adhesion or weight placed on the drivers must be greater than the resistance of the train, and this weight is usually limited by the condition of the road bed, weight of rails and strength of bridges. Here is where the engineering department specify to the mechanical officers the number of pounds that may be placed on the driving wheels of the locomotive. The diameter of the driving wheels, diameter of cylinders, length of stroke of the piston in inches and the number of pounds steam pressure per square inch carried on the boiler will enable us to approximateliy determine the tractive power, when the use of a dynamometer car is not available. The tractive power, developed by a single expansion locomotive at slow speed may be ascertained by assuming that 85 per cent of the boiler pressure will equal the mean effective pressure in the cylinders and using the formula:

$$\frac{C^2 \times S \times P}{D} - T$$

Now this is not at all hard and a little time will make this and other formulas easy to figure.

C^2 indicates that the diameter of the cylinder should be multiplied by itself, or squared.

S equals the stroke of the piston in inches.

P equals the mean effective pressure in pounds or 85 per cent of the boiler pressure.

D equals the diameter of the driving wheels in inches and placed under the line means that when the diameter of the cylinder is multiplied by itself or squared, that number multiplied by the number of inches of stroke and then by the number of pounds mean effective pressure all this above the line should be divided by D or the diameter of the driving wheel in inches will equal T or the tractive power.

EXAMPLE: An engine 20x26″ cylinders, 56″ wheels, 200-lb. boiler pressure.

C^2—20 x 20 = 20 × 20 = 400

S—26″ = 400 × 26 = 2400

85% of P— 200 × .85 = 800

1000 + 1600 = 10400 + 170

170.00 = 708000 + 10400

Diam. of Driver 56) 1768000 (31,571 Pounds, Tractive Force

168

88
56

320
280

400
392

80
56

4

$$T = \frac{C^2 \times S \times P}{D} \text{ or } 31{,}571 \text{ Pounds.}$$

31.571 pounds tractive power developed by the engine that can be used to overcome the resistance of the locomotive and train. This rule is applicable to any size single expansion engine.

For a two-cylinder compound use this formula:

$$\frac{C^2 \times S \times \frac{3}{4}P}{D} - T$$

using two-thirds of the boiler pressure and considering the high pressure cylinder only.

EXAMPLE: What is the tractive power of a two-cylinder compound:

Cyls. $\frac{22}{33}$ x 26 " Drivers 63 " Boiler Pressure 210 lbs.

22
22
—
44
44
—
484
26
—
2904 ¾ of 210 = 140 lbs.
968
—
12584
140
—
503360
12584
—
D = 63 ") 1761760 (27,964 Pounds, Tractive Force
126
—
501
441
—
607
567
—
406
378
—
280
252
—
28

The tractive power of a four-cylinder compound may be ascertained by the following formula:

$$\frac{C^2 \times S \times \frac{3}{4}P}{D} + \frac{C^2 \times S \times \frac{1}{4}P}{D} - T$$

Work this out separately for the high and the low pressure cylinders the same as was done for the simple and add the quotients.

EXAMPLE: What is the tractive power of a four-cylinder compound:

Cyls. $\frac{15}{25}$ x 26 " Drivers 73 ", Boiler Pressure 220 lbs.

High Pressure Cylinder.

15
15

75
15

225
26

1350
450

5850
¾ of 220 = 146

35100
23400
5850
---
73) 854100 (11,700
73

124
73

511
511

00

Low Pressure Cylinder.

25
25

125
50

625
26

3750
1250

16250
¾ of 220 = 55

81250
81250
---
73) 893750 (12,243
73

163
146

177
146

315
292

230
219

11

11,700 + 12,243 = 23,943 T.

TRAIN RESISTANCE OR LOCOMOTIVE RATING.

To overcome the resistance of one ton, 2,000 lbs., on a straight and level track at a speed of ten miles per hour or less, careful tests have demonstrated that it varies from 5 to 8 lbs. per ton, or an average of 6½ lbs. per ton. It is safe to allow 8 lbs. per ton for train resistance on a level, and by dividing the tractive power by 8 it would give the number of tons rating. This rule covers the axle or journal and rolling friction only. If on a grade, multiplying the feet per

mile rise in grade by .3788 will give the resistance due to grade per ton and will be sufficiently correct to establish a rating in the absence of a regular test or a dynamometer car; or if preferred, add 3/8 lbs. = to .375 per ton for each foot per mile rise in the grade. Either of the above decimals will answer for grade resistance. Curve resistance may be figured as 9-16 lbs. per ton for every degree of curve, 9-16=.5625. Using this decimal and multiplying by the number of degrees in the curve we get the curve resistance.

EXAMPLE: What is the resistance per ton of train on a grade of 100 feet per mile with 4 degree curve.

Allowing 8 lbs. for friction.
100 x .375= 37.5 lbs. for grade.
4 x .5625= 2.25 lbs. for curve.
47.75

we have 47.75 lbs. resistance per ton.

These figures are not given as absolutely correct in establishing a rating, but will serve to work from in making up trains for test. The only correct method to rate an engine is to take several engines of the same class and make actual tests in service to get the hauling capacity, then reduce the tonnage of train to meet the requirements of the service and leave a sufficient margin of power to insure proper time being made under average conditions. The old method of the last car she will pull has lost out long ago, and the most economical rating at the present time is a train that can be handled and gotten over the road without tying up opposing or following trains.

Handy Rules in Arithmetic.

To find the circumference of a circle multiply its diameter by 3.1416.

To find the diameter of a circle multiply its circumference by .31831.

To find the area of a circle multiply the square of its diameter by .7854.

To find the cubic inches in a ball multiply its cube of diameter by .5236.

To find the revolutions of drivers per mile divide 1680 by the diameter of the wheel in feet.

To find revolutions per minute multiply the speed in miles per hour by 28 and divide the product by the diameter of the driving wheel in feet.

To find piston speed in feet per minute multiply revolutions per minute by twice the stroke of piston in feet.

To find the speed of train per second multiply speed in miles per hour by 22 and divide by 15.

To find time when rate of speed and distance is given multiply distance by 60 and divide by rate of speed.

To find rate of speed when distance and time are given, distance multiplied by 60 and divided by the time in minutes.

To find the distance when the time and rate of speed are given, multiply the time by the rate of speed and divide by 60.

To find the number of tons of coal in a bin: Length, height and width of pile in feet multiplied together, divide by 30 for hard coal, by 35 for soft coal, by 128 for cords of long wood, and by 135 for cords of sawed wood.

To find the pounds of coal used per 100-ton mile multiply pounds of coal by 100 and divide by tons multiplied by the miles hauled.

To find the pressure in pounds per square inch of a column of water multiply the height of the column in feet by .434.

FIG. No. 37

shows Baldwin Locomotive Works curve representing the revolutions per mile of driving wheels of various diameters. The diameter of the wheels is designated by the numbers at the top of the chart, and the revolutions per mile by the numbers at the left margin. A perpendicular line from any number representing the diameter of the wheel followed to its intersection with the curve, then out on the horizontal line to the marginal number on the left, will give the number of revolutions for the diameter of wheel.

FIG. No. 38

gives piston speed in feet per minute for drivers of different diameters and various strokes at a speed of 10 miles per hour; for greater speeds they must be multiplied by the factor representing the speed. In using the plate follow the perpendicular line from the number representing the driver wheel in inches until it intersects the curve representing the stroke of piston; following the horizontal line to the marginal number at the left will give the piston speed in feet per minute for the given wheel and stroke.

BALDWIN LOCOMOTIVE WORKS

Revolutions of Driving Wheels per Mile.

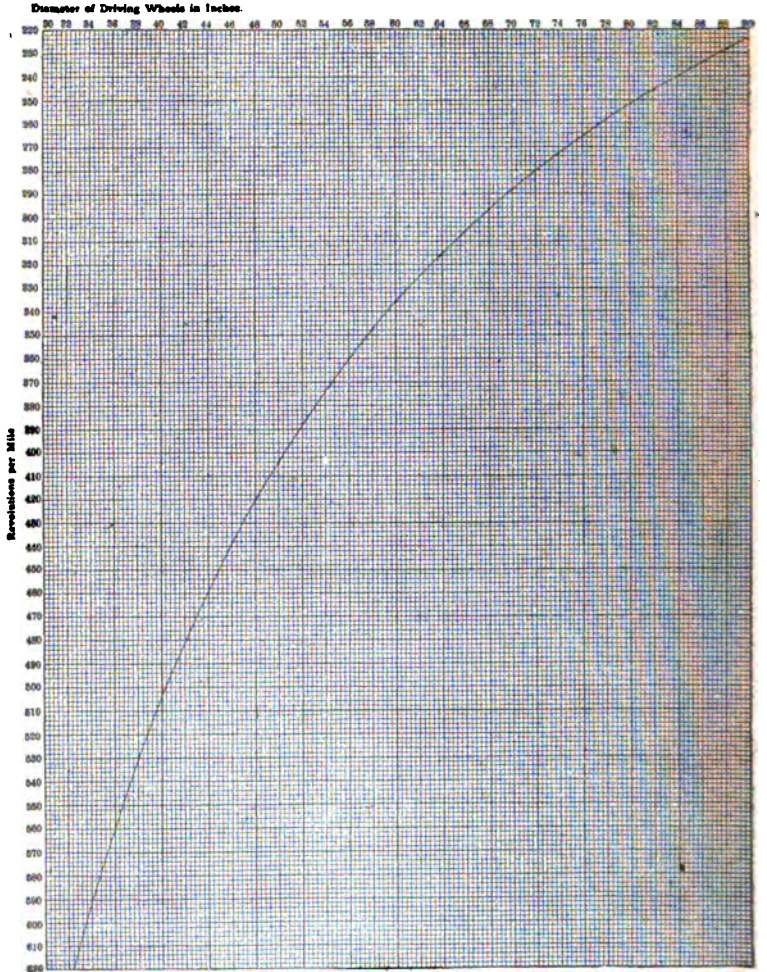


Fig 37

BALDWIN LOCOMOTIVE WORKS.

Piston Speeds in Feet per Minute at Engine Speed of Ten Miles per Hour.

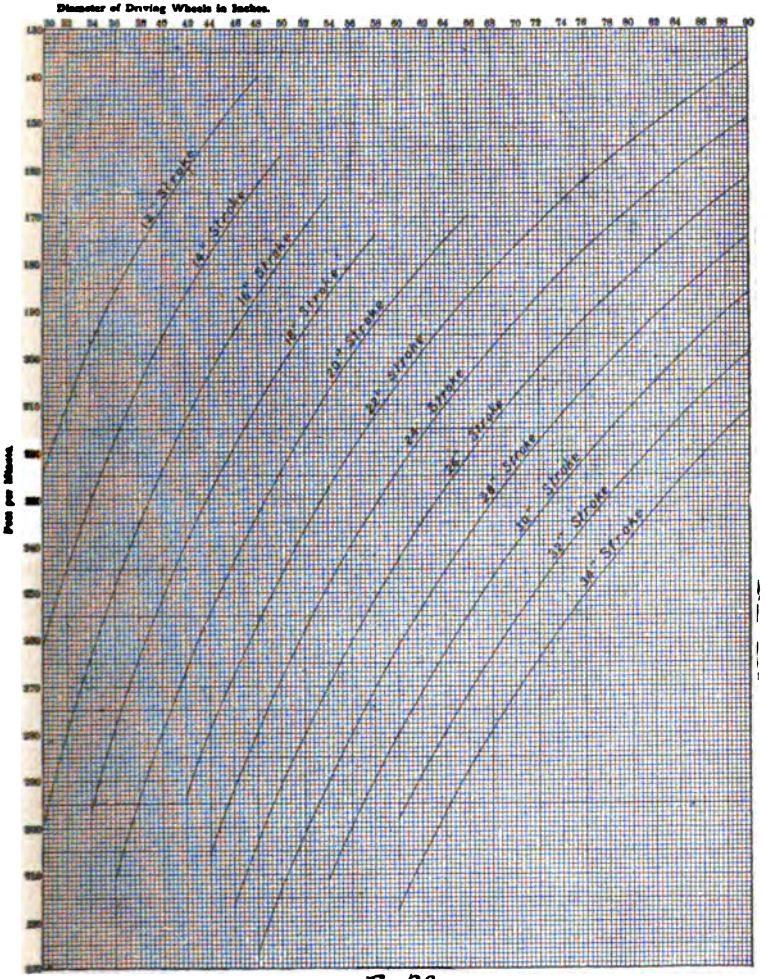


Fig.38

SECONDS PER MILE IN MILES PER HOUR.

Seconds per Mile.	Miles per Hour.	Seconds per Mile.	Miles per Hour.	Seconds per Mile.	Miles per Hour.
24	150	47	76.6	69	52.1
25	144	48	75	70	51.4
26	138 5	49	73.4	71	50.7
27	133.3	50	72	72	50
28	128.5	51	70.5	73	49.3
29	124.1	52	69.2	74	48.6
30	120	53	67.9	75	48
31	116.1	54	66.6	76	47.3
32	112.5	55	65.4	77	46.7
33	109	56	64.3	78	46.1
34	105 8	57	63.1	79	45.5
35	102.8	58	62	80	45
36	100	59	61	81	44.4
37	97.3	60	60	82	43.9
38	94.7	61	59	83	43.3
39	92.3	62	58	84	42.8
40	90	63	57.1	85	42.3
41	87.8	64	56.2	86	41.8
42	85.7	65	55.3	87	41.3
43	83.7	66	54.5	88	40.9
44	81.8	67	53.7	89	40.4
45	80	68	52.9	90	40
46	78.2				

DECIMAL EQUIVALENTS.

1-64 in.	.015625	23-64 in.	.359375	11-16 in.	.6875
1-32	.03125	3-8	.375	45-64	.703125
3-64	046875	25-64	.390625	23-32	.71875
1-16	.0625	13-32	.40625	47-64	.734375
5-64	.078125	27-64	.421875	3-4	.75
3-32	09375	7-16	.4375	49-64	.765625
7-64	.109375	29-64	.453125	25-32	.78125
1-8	.125	15-32	.46875	51-64	.796875
9-64	.140625	31-64	.484375	13-16	.8125
5-32	.15625	1-2	.5	53-64	.828125
11-64	.171875	33-64	.515625	27-32	.84375
3-16	.1875	17-32	.53125	55-64	.859375
13-64	.203125	35-64	.546875	7-8	.875
7-32	.21875	9-16	.5625	57-64	.890625
15-64	.234375	37-64	.578125	29-32	.90625
1-4	.25	19-32	.59375	59-64	.921875
17-64	.265625	39-64	.609375	15-16	.9375
9-32	.28125	5-8	.625	61-64	.953125
19-64	.296875	41-64	.640625	31-32	.96875
5-16	.3125	21-32	.65625	63-64	.984375
21 64	.328125	43-64	.671875	1	1
11-32	.34375				

WHEELS.

Diameter, Circumference and Revolutions per Mile.

Diameter in Inches.	Circumference in Feet.	Revolutions per Mile.	Diameter in Inches.	Circumference in Feet.	Revolutions per Mile.
18	4.712	1119.76	48	12.57	420.0
20	5.236	1008.4	50	13.00	406.4
22	5.759	916.8	52	13.61	387.9
24	6 283	838.4	54	14.14	373.4
26	6.81	775.3	56	14.66	360.2
28	7.36	720.3	58	15.18	347.8
30	7.85	672.6	60	15.71	336.1
32	8.377	630.3	62	16.23	325.3
33	8.64	611.1	64	16.75	315.2
34	8.901	593.2	66	17.28	305.5
36	9.42	560.5	68	17.80	296.6
37	9.686	545.1	70	18.36	288.1
38	9.95	530.6	72	18.85	280.1
40	10.47	504.2	78	20.42	258.6
42	11.00	480.0	84	21.99	240.1
44	11.52	458.3	90	23.56	224.1
46	12.04	438.5	96	25.16	210.1

TEMPERATURE OF STEAM AT VARIOUS BOILER PRESSURES.

Boiler Pressure.	Degrees Fahr.	Boiler Pressure.	Degrees Fahr.	Boiler Pressure.	Degrees Fahr.
0	212	110	344	165	372.8
5.3	228	115	347	170	375.1
15.3	250.4	120	349.9	175	377.3
25.3	267.3	125	352.8	180	379.5
35 3	281	130	355.5	185	381.5
45 3	292.7	135	358.2	190	383.7
55.3	302.9	140	360.8	195	385.8
65.3	312	145	363.3	200	387.8
75.3	320.2	150	365.8	205	389.7
85.3	327.9	155	368.1	210	391.7
100	337.8	160	370.6	215	393.6
105	340.9				

CHAPTER VI.

A CHAPTER OF "DON'TS" FOR ENGINEERS AND FIREMEN.

"FIRST. *Don't* think because you are only one engineer or fireman, that what you do does not amount to much. It is the little drops of water that make the mighty ocean, and the little grains of sand that make up this earth of ours; so each individual, in the aggregate, can do a great deal. If each engine crew saves one-quarter of a ton or five hundred pounds of coal, this on a thousand locomotives would result in a daily saving of two hundred and fifty tons, or in round figures $157,000 a year.

"SECOND. *Don't* neglect being at roundhouse in ample time to examine the firing tools on the engine before leaving the roundhouse. See that your ashpan, grates and flue-sheets are in good condition to make the run.

"THIRD. *Don't* fill the boiler full of water as soon as you get out of the house. Leave a space so the injector can be worked to prevent popping while air pump exhaust is fanning the fire, pumping air to make the terminal air brake test. If you do this your fire will be in better condition to pull out with. The noise of open pop prevents trainmen from locating leaks.

"*Don't* forget to start the lubricator a few minutes before leaving a terminal. Set it to feed

regularly. The proper lubrication of valves and cylinders saves coal.

"FOURTH. *Don't* forget, when starting trains, to do so carefully, thus preventing damage to drawbars and draft rigging. By so doing you will save serious delays to your own as well as other trains. All delays mean extra fuel consumption to make up time lost.

"*Don't* neglect using the blow-off cock, as it keeps the boiler clean and water in good condition, and insures better circulation in boiler. Result: Better steaming engine and a saving in coal.

"FIFTH. *Don't* allow the engine to slip. This is an unnecessary waste of coal, wears out tires and rails, causes great damage to pins, axles and running gear, and generally results in spoiling a fire.

"SIXTH. *Don't* pull out of a station with a train (after engine has stood for a while, and fire was allowed to get low) without first giving the fireman a chance to build up the fire. The time lost waiting to do this will save coal, and can better be made up before reaching the next station. Remember this when you get a time order.

"SEVENTH. *Don't* leave the reverse lever down in corner longer than necessary when pulling out of stations. No rule can be made to govern how the throttle and reverse lever should be used. This must be acquired by practice and observing the performance of the engine. Bring the lever up gradually as speed is acquired. The lever hooked well towards center of quadrant, with

throttle well open, usually gives better results than using the throttle to govern the speed. Up to five years ago we considered it good practice with our smaller power to run with wide open throttle, and as short a point of cut-off as possible consistent with weight of train; but in our heavier and larger engines we find that it is better at many times to throttle the engine. Particular attention is called to all wide fire-box type of locomotives. The engineer can permit the reverse lever in these engines to remain low in the quadrant when starting from a station for a greater length of time than with the other types of locomotives without pulling the fire or losing steam. When you are running on short time, it would be good judgment for the engineer to take advantage of this when pulling out from a station. In this engineers will use their best judgment.

"EIGHTH. *Don't* put four or five or more shovelfuls of coal into the fire at once. One or two shovelfuls will give better results, and these two should not be thrown in the same spot. It is good practice to fire on one side of the box at one time, and the next time on the other side of the box, in order that the bright fire on one side may take up the gases from the fresh coal on the other side. This will reduce the smoke and give more steam.

"Always fire as light as possible consistent with your work. Very heavy firing will make your flues and staybolts leak, and in time will crack your fire-box sheets. The reason for this is that

when you have a very heavy fire the air will not pass up through it readily, and the gases pass off, because there is not sufficient oxygen to unite with them to produce combustion, and as the gases must get air from somewhere, the air is then pulled through the fire-door, causing the chilling of flues and sheets as referred to above.

"NINTH. *Don't* allow steam to escape at pops unnecessarily. Frequent blowing off at pops shows improper judgment, and implies that the engine crew is not practicing economy. Tests have demonstrated that ¼ lb. per second, or 15 lbs. per minute, is wasted. This amounts to about one ordinary scoopful, and in most cases may as well have been thrown on the ground as into the firebox. There are only 133 scoopfuls in a ton of coal, so you can see that you would only have to have your pops open one hundred and thirty-three minutes in a whole day in order to throw a ton of coal away.

"TENTH. *Don't* open the firebox door to prevent steam blowing off at pops when engine is working; dropping dampers is a better practice. The supply of air is cut off, and combustion is partially suspended. When engine stops blowing off, open dampers again before putting in coal. This method keeps fire in better condition and saves coal. You have no doubt noticed that on a certain class of locomotives, when working hard on a hill, you have to shut your dampers in order to keep your fire from turning over. This is because the exhaust pulls too much air up through the grates, and causes your coal to be too active.

and to prevent this activity of coal, as well as increased combustion which follows, we consider it a good thing to drop your dampers, as per above.

"ELEVENTH. *Don't* insist upon having the maximum steam pressure with pops opening occasionally when handling light trains, when less pressure will handle the train on time, thus avoiding the opening of pops.

"TWELFTH. *Don't* forget, when engine is shut off for stations, to drop your dampers, opening the firebox door slightly, if necessary, and using the blower to carry off the black smoke.

"THIRTEENTH. *Don't* blame the engine or coal if engine is not steaming properly, before you have ascertained whether or not both of you are doing your duty. Talk it over; see if injector is not supplying more water than is being used, or that fireman is not firing too light or too heavy. Heavy firing is responsible for more poor steaming engines than the lighter method. You all know some engine crews have better success than others, with same engines and conditions. Think a little; there must be some cause for this.

"*Don't* wait until you get the signal to pull out before building up the fire. This should be done gradually until the proper thickness has been reached. A good fire to start with is essential to maintain the proper steam pressure, while engine is working hard getting train under way. Afterwards distribute the coal evenly on sides, ends and corners. Do this systematically, keeping in mind where you have placed the last

shovelful, thus avoiding getting holes in fire, and prevent piling up coal all in one place. Endeavor to keep the steam pressure uniform, with as little black smoke as possible. Experience has taught that engines with draft appliances properly adjusted require very little coal in center of firebox.

"FOURTEENTH. *Don't* permit the water to get so high in boiler that it is carried over into the valves and cylinders. This usually occurs when pulling out of stations, and the water carries off the oil, which not only results in cut valves and cylinders, but the extra friction damages the entire valve motion, to the detriment of the power of engine and the coal record.

"*Don't* gauge the amount of water an engine will safely carry by water coming out of stack. Keep it low enough to insure dry steam being used, because moist steam has the same effect as water. Usually one-half glass or two gauges give best results. Be careful, however, that when ascending a grade, and you are about to pitch over the other side, that you have sufficient water to keep your crown-sheet thoroughly covered. If your custom has been to carry high water, try less and note results in better handling of tonnage, also saving in coal and oil.

"FIFTEENTH. *Don't* neglect to take advantage of your excess steam before your engine is about to pop off, by making a heater of your injector, blowing steam back into the tank to warm the cold water, but avoid getting it so hot that the injector will not lift the water. By doing this

you will keep your engine from blowing off at pops when standing at stations after the boiler is filled up. You have all tried warming the water in the tank to help a poor steaming engine, with good results. What is good for a poor steaming engine will surely help a good steaming engine dó better. Try it and you will find that it will not only save work for the fireman, but will make a better coal record for the engine crew, besides keeping the tank from sweating, which you are aware spoils paint.

"SIXTEENTH. *Don't* think the fireman alone to blame for your coal record. The best and most economical fireman cannot make a showing with an engineer who supplies more water to boiler than is being used, and who shuts injector off only when boiler is pumped full. The proper handling of the injector is one of the most important matters in saving coal. Feed water to boiler according to demands. If on through train keep water level as possible. If on way freight or switch trains, lose a little water between stations. Fill up again while drifting into, standing or switching at station. The advantages of supplying less water than is being used between stations are: It requires less coal to keep up steam pressure when running; also leaves a space so injector can be worked to avoid pops opening, and heavier fire can also be maintained to do switching, without the possibility of the fire being pulled.

"*Don't* pull out after making a stop with injectors working. The cool water introduced during

period throttle was shut off is put in circulation throughout the boiler, and pointer on gauge drops back from five to twenty-five pounds. The fireman must then fire heavier to regain the lost steam, and naturally will use more coal. This condition exists also when engine has gone down grade with throttle shut or slightly open. Shut the injector off before opening the throttle. If this is not your practice, try it and note the difference.

"SEVENTEENTH. *Don't* wait for the pops to open, and use this as a signal to put on the injector. Keep an eye on the air gauge, steam gauge and water glass. You all know this can be done without distracting your attention from the track ahead. A look for an instant every mile or two will keep you informed, and is a good habit. Doing this will also keep you posted on air pressure, and may avoid difficulties should the air pump stop. The fireman should also keep an eye on the water glass, as the engineer is sometimes compelled to keep the injector at work to prevent the engine blowing off. When glass is full, the fireman should fire lighter, to give the engineer a chance to shut off the injector, and not have engine blow off. However, this condition should only exist when injector cannot be worked fine enough to just supply amount used. This sometimes occurs when card time is slow, or on down grade, or when running with light train.

"EIGHTEENTH. *Don't* put too much coal under the arch of engines with sloping fireboxes, because these engines naturally pull the coal ahead.

which results in forward section of grates becoming stuck and clinkered over, and fire is pulled in back end of firebox. Experience and observation will teach you to put most of the coal in back end of firebox.

"NINETEENTH. *Don't* think engine having two firebox doors requires twice the quantity of coal it would if engine had but one. The extra door is for the purpose of distributing the coal more evenly over the grate surface, with less effort on the part of the fireman.

"TWENTIETH. *Don't* shovel large chunks of coal into firebox, because you find them on the tank. The coal house men have instructions to break it the size of an apple. If not properly broken, report it to Road Foreman of Engines or to Master Mechanic, instead of fellow engineers or firemen, but don't think it a hardship to break some occasionally. Better break it than to throw in large chunks. They are foundations for clinkers.

"TWENTY-FIRST. *Don't* expect the fireman to fire the engine with one or two scoops to each fire, and also ring the bell for highway crossings and stations. Some engineers expect this. If engine is equipped with an air bell-ringer, get into the habit of starting the bell-ringer when blowing the whistle. By so doing, the habit will become as fixed as whistling for crossings and stations. Besides, it is just as important. Remember the engineer is responsible.

"TWENTY-SECOND. *Don't* put in a heavy fire about the time the engine is shut off for a station or down-grade. The heavy cloud of black smoke

is evidence the engine crew is not working in harmony or practicing economy. If on train that stops at all stations, the fireman should guard against it and learn when to stop firing. He will be governed by grade, service and weather conditions. If train does not make all station stops, the engineer should keep the fireman informed of intended stops.

"TWENTY-THIRD. *Don't* forget that different qualities of coal and different make of grate used, govern the shaking of grates. Coal that fills up and clinkers, requires more attention than the better grade. The object is to keep the grates free, so the proper amount of air can be admitted,

"TWENTY-FOURTH. *Don't* neglect cleaning your fire on trains that are long hours on the road. Make use of the first opportunity. You will get better results with less labor and coal, and avoid leaky flues. Better clean out a small amount two or three times than not clean it at all.

"*Don't* take coal or water oftener than necessary, as it requires an extra amount of coal to again get a heavy train in motion, especially on a grade. Good judgment is required, in order not to run short before getting to next coal chute or water tank. Where possible take water only from tank containing good water, and as little as you can from tanks containing poor water.

"TWENTY-FIFTH *Don't* forget that leaks in the air pressure are being kept up by an equal amount of steam pressure. As it takes coal to make steam, air leakage means a waste of coal. Keep apparatus on your engine tight, and insist on trainmen doing their part.

"TWENTY-SIXTH. *Don't* try to put more coal on tank than will lay on it securely. All coal dropped off by overloading is wasted. Also keep coal from falling out of gangway when running. This may be only a little each day, but it all counts against your coal records besides it looks badly when strewn along the tracks. You can not save coal by the ton; it must be in pounds, which in time makes tons.

"TWENTY-SEVENTH. *Don't* forget to make an intelligent report on your work slip on arrival at Round House. Consult your fireman in regard to any defect that has come to his notice, especially with grates, dampers or firing tools.

"TWENTY-EIGHTH. *Don't* neglect reporting the pop valves ground in when leaking or when they blow back eight or ten pounds before seating. Also report leaky piston rod and valve stem packings, or if cylinder packing or valves are blowing. All these leaks draw on the coal pile unnecessarily; it takes coal to generate the wasted steam. This also applies to leaky steam heat appliances, cylinder cocks, etc.

"TWENTY-NINTH. *Don't* neglect looking at coal report each month to see how you stand in relation to others in same service with whom you are comparable. The other crews get the same pay you do, and it should be your aim to be as economical with both fuel and supplies as they are, other things being equal. Keep posted and be with the average. It will be to your credit and interest some time; therefore aim to be at the top.

"THIRTIETH. *Don't* think when coal report shows you using only two pounds more per 100 ton mile than other crews in same service, it is close enough. This means two pounds more used for every mile you hauled 100 tons—or another way, two pounds for every 100 tons hauled one mile. Figure this up and you will find in hauling 1,000 tons 100 miles, a difference of 2,000 pounds or one ton. This method of showing up the individual record is more equitable to all than on basis of mile run per ton of coal.

"THIRTY-FIRST. *Don't* think, after reading over this chapter of "*Don'ts*" you should save coal to the detriment of the service. The actual amount required to make up time, keep on time, or handle tonnage, is not what we are trying to save; it is the waste."*

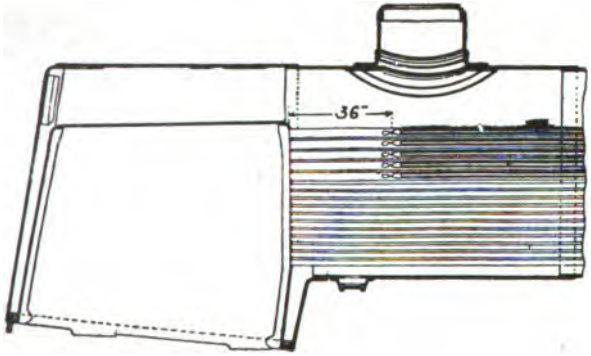
* R. Quayle.

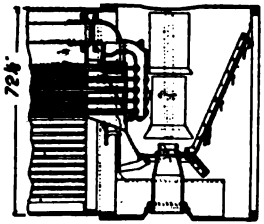
CHAPTER VII.

THE LOCOMOTIVE SUPERHEATER.

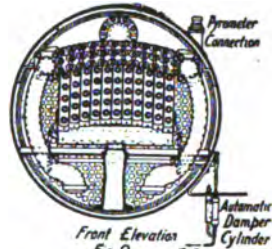
In the progress made, looking toward a more complete utilization of steam in the locomotive, the line along which developments were made for many years was that of compounding the cylinders and thus using the steam more than once. In recent times, however, exhaustive tests have been made both abroad and in this country with what is known as the "superheater" which is an attachment to the locomotive designed to reduce cylinder condensation by superheating the steam. It is claimed that this superheating results in economy of water consumption and also economy of fuel. Superheated steam also affects an economy by reason of its increased volume. Speculation has been made as to which development—Compound Cylinders or the Superheater—will prove to add most largely toward locomotive capacity. Possibly a combination of the two may some day be effected with advantage.

"Two types of superheaters have been giving considerable service, the Schmidt and the Pielock. The former is made in two ways; one with a nest of small tubes or pipes concentrically arranged in several rows in the bottom of the smokebox, and heated by means of a special flue about 8 inches in diameter, allowing fire from the firebox to pass forward and heat the pipes, through which the steam is made to pass on its way from



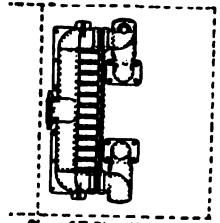


Vertical Section
Fig. 1.

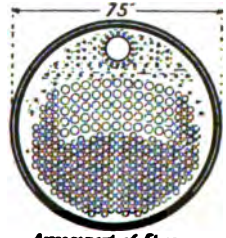


Front Elevation
Fig. 2

Detail of Back End of Superheater Tube
Fig. 3.



Plan of T Pipe, Headers, etc.
Fig. 4.



Arrangement of Flues
Fig. 5.

THE SCHENECTADY SUPER-HEATER.

the throttle to the cylinders; the other by means of loops of small (about 1 inch) pipes extending backward through several rows of large flues (5 inches diameter) in the upper portion of the boiler, the steam passing through these on its way to the steam chests. * * * *

"The Pielock superheater consists of a cubical box, placed in the center of the boiler, directly under the dome, and forming a water-tight compartment about the flues. The steam is taken in at the top of the box and after being led in a winding path about the flues is delivered superheated to the throttle valve in the dome. * * * The heating surface of the boiler is reduced by the amount in the superheater.*

The following is a description of a superheater known as the "Schnectady" or "Cole" superheater for locomotives.†

It is claimed that this type of superheater overcomes objectionable features of previous superheaters, which have been (1) the use of bent tubes and (2) the necessity of dismantling the whole superheater in order to gain access to any single leaky boiler tube.

A feature of construction in this superheater is the T-pipe, the regular conventional T-pipe being replaced by one of special design, shown in Figs. 1, 2 and 4; it will be seen that this T-pipe is subdivided into two compartments by a horizontal partition, and that it extends nearly across the smoke box; steam entering the T-pipe from the dry pipe is admitted to the upper compartment

*G. R. Henderson. "Locomotive Operation."

†This superheater was designed by Mr. F. J. Cole, Mechanical Engineer, American Locomotive Company.

only. To the front side of the T-pipe are attached eleven header castings, the joint being made with copper wire gasket, as in the steam chest practice; each header casting is also subdivided into two compartments but in this case by a vertical partition; five pipes or flues of 1 1-16-in. outside diameter are inserted through holes (subsequently closed by plugs) in the front wall of each header casting, these 1 1-16-in. tubes having been expanded into special plugs, are firmly screwed into the vertical partition wall; these five 1-16 in. tubes are enclosed by five 1¾-in. tubes which are expanded into the rear wall of the header casting in the usual way; each nest of two tubes (one 1 1-16-in. and one 1¾ in.) is encased by a regular 3-in. boiler tube, which is expanded into the front and back tube sheets as usual; the back end of each 1 1-16-in. tube is left open; the back end of each 1¾-in. tube is closed; the back ends of the two tubes being located at a point about 36 inches forward from the back flue sheet. The detail arrangement and grouping of the three flues are shown by Fig. 3. The back end of the 1¾-in. tube is closed by welding, and the tail is so formed as to support this tube in the upper part of the 3-in. tube, thus leaving a clear space below. Figure 1 indicates that the 1 1-16-in. tubes are concentric with the 1¾-in. tubes at their back ends, but the fact is the 1 1-16-in. tube is allowed to drop and rest on the bottom of the 1¾-in. tube, as shown by Fig. 3.

Steam from the dry pipe enters the upper compartment of the T-pipe and thence enters the forward compartments of each of the eleven header castings, and then passes back through each of the fifty-five 1 1-16-in. tubes, thence for-

ward through the annular spaces between the 1 1-16-in. tubes and the 1¾-in. tubes to the rear compartments of each of the eleven header castings, thence into the lower compartments of the T-pipe, thence by the right and left steam pipes to the cylinders. In passing forward through the 1¾-in. tubes the steam is superheated by the smoke box gases and products of combustion passing through the 3-in. tubes.

In this particular design fifty-five 3-in. tubes are inserted in the upper part of the flue sheets, thus displacing as many of the regular smaller tubes as would occupy the same space. The arrangement of flues is clearly shown by Fig. 5.

In applying the superheater to a locomotive it is necessary to provide some means by which the superheater tubes shall be protected from excessive heat when steam is not being passed through them. In this design this is accomplished by an automatic damper, as shown in Figs. 1 and 2. That portion of the smoke box below the T-pipe and back of the header casting, is completely enclosed by metal plates; the lower part of this enclosed box is provided with a damper which is automatic in its action; whenever the throttle is opened and steam is admitted to the steam chests the piston of the automatic damper cylinder, shown in Fig. 2, is forced upward, and the damper is held open, but when the throttle is closed the vertical spring immediately back of the automatic damper cylinder (and concealed by it in Fig. 2) brings the damper to its closed position, so that heat is not drawn through the 3-in. tubes when the engine is not using steam. In this way the superheater tubes are effectively prevented from being burned. In introducing the group of

3-in. tubes and applying the superheater, there is a slight loss of heating surface, but it is more than offset, as regards economical results, by the superheating process.

A pyrometer is inserted in the left steam pipe, as shown in Fig. 2.

The piston rod metallic packings must be such as will not be unfavorably affected by the excess heat, in the cylinder.

When superheated steam is used great care must be taken as regards lubrication of the cylinders, usually forced feed is resorted to instead of the usual gravity feed.*

*The subject of superheaters is more fully and comprehensively treated in another volume of the "Science of Railways" series, devoted to Locomotive Appliances.

CHAPTER VIII.

VALVES AND VALVE GEARS.

The essential elements of the steam distributing valve are that the steam must be admitted to the cylinder at one end only, at one time; that the steam must be allowed to escape from the opposite end of the cylinder before steam is admitted to the first end, and the steam must not be allowed to escape from the steam chest into the exhaust passage.

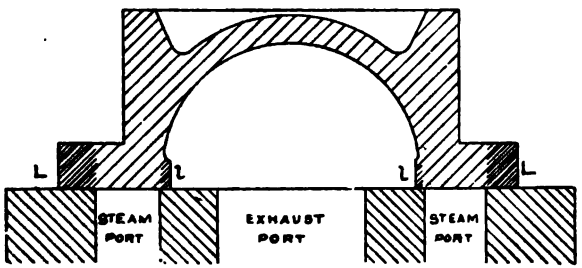


FIG. 1

PLAIN SLIDE VALVE.

The most common form of valve, is the plain slide valve, which is outlined in Fig. 1. The simple valve is indicated by the lightly shaded portion and the steam and exhaust laps by the blackened portions "L" and "l." In order that

the meanings of the various terms used in connection with valves and their gears may be understood, the following definitions and explanations are given.

Lap is that portion of the valve which overlaps the steam ports when the valve is in its mid-position. The lap on the edge of the valve which admits steam to the cylinder, is called "steam lap" and that on the edge which allows the steam to escape from the cylinder to the exhaust passage is called "exhaust lap." For some classes of service this exhaust lap is made a negative quantity and becomes "exhaust clearance," or as more commonly termed, "clearance."

Cut-off is the cutting off of the supply of live steam, or steam in the steam chest, from the cylinder before the piston has completed its stroke and thus making use of the expansive force of the steam.

Release is the opening of the exhaust port to the cylinder through the exhaust-arch of the valve and allowing the expanded steam to escape to the atmosphere.

Expansion is the expanding of the steam in the cylinder from a small volume at a high pressure to a large volume at a low pressure. The period of expansion extends from "cut-off" to "release." The amount of expansion is regulated by the steam and exhaust lap used on the valve.

Point of compression is the stopping of the escape of the exhaust steam before the piston has reached the end of its stroke.

Compression is the compressing of the entrapped exhaust steam at the point of compression by the piston as it advances in its stroke. It con-

tinues either up to the end of the stroke or to the point of "pre-admission."

Back pressure is the pressure exerted by the steam against the piston while the exhaust port is open after the piston has commenced its return stroke.

Admission is the admitting of steam into the cylinder. This point is either at the beginning of the stroke or slightly before. If before, it is called "pre-admission."

Lead is the amount or width of opening of the steam port for the admission of steam to the cylinder that the valve setting gives when the piston is at the beginning of its stroke. The effect of lead is to permit an earlier cut-off, to increase compression and to secure as nearly full steam chest pressure as possible in the cylinder up to the point of cut-off, by giving a large port opening as the piston commences its stroke.

Travel is the distance that the valve itself travels. Over-travel is the distance that the steam edge of the valve travels after the steam port is wide open.

Seal is the overlapping of the steam edges of the valve to prevent leaking.

Clearance is the volume of the space between the piston and the valve, when the piston is at the end of its stroke.

With no outside or steam lap, there would be no expansion, and with no inside or exhaust lap, the compression and release would both occur at the same time. Outside lap delays the admission of steam and hastens the cut-off, consequently allowing greater expansion. Inside lap hastens compression and prolongs the expansion by delaying

the point of exhaust. Inside clearance, on the contrary, will delay the compression and hasten the release of the exhaust.

We will now investigate how the valve admits and exhausts the steam to and from the cylinder. As the valve, Fig. 2, moves in the direction of

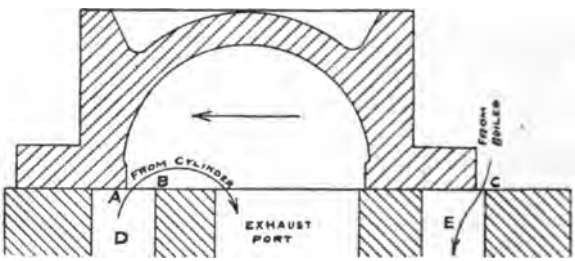


FIG. 2

ADMISSION AND EXHAUST OF STEAM TO AND FROM VALVE.

the arrow, the exhaust edge A of the valve passes the point B on the seat. At this time steam will commence to escape from the cylinder through the steamport D into the exhaust port; a short time after exhaust takes place at B, the steam edge C of the valve begins to open the port E, which admits steam into the cylinder from the steam chest. On the return stroke of the valve, the same events occur, only at the opposite edges of the valve and seat.

It has been found difficult at short cut-offs to get the full steam chest pressure at the beginning of the stroke with the plain slide valve without excessive lead, and to overcome this difficulty, the Allen valve, Fig. 3, was designed. This valve

has a supplementary port, supplying steam to one steam port from both sides of the valve at the same time, thus giving double the port opening for the same travel of the valve and a consequent increase of steam pressure in the cylinder. This

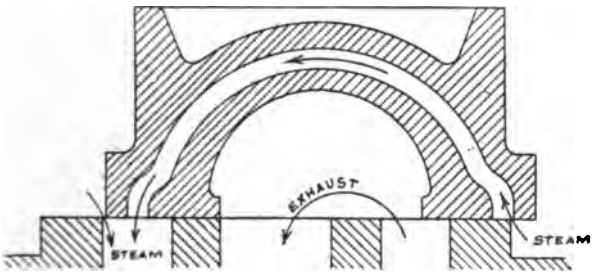


FIG 3
ALLEN PORTED VALVE.

valve has given excellent results, because it furnishes plenty of steam at higher initial cylinder-pressure with short valve travel, and is therefore especially adapted to high speed engines working in short cut-offs.

On top of a plain, unbalanced slide valve of any type, there is a total pressure of the steam pressure per square inch in the chest multiplied by the area of the valve; as the locomotives and valves were built larger, it became almost impossible for one man to reverse such a valve; and to overcome this, the valves were "balanced," that is the steam pressure was removed from a portion of the top of the valve.

One of the most frequently used types of balanced valves is known as the Richardson. Fig. 4 shows it outlined as in common use. A is the

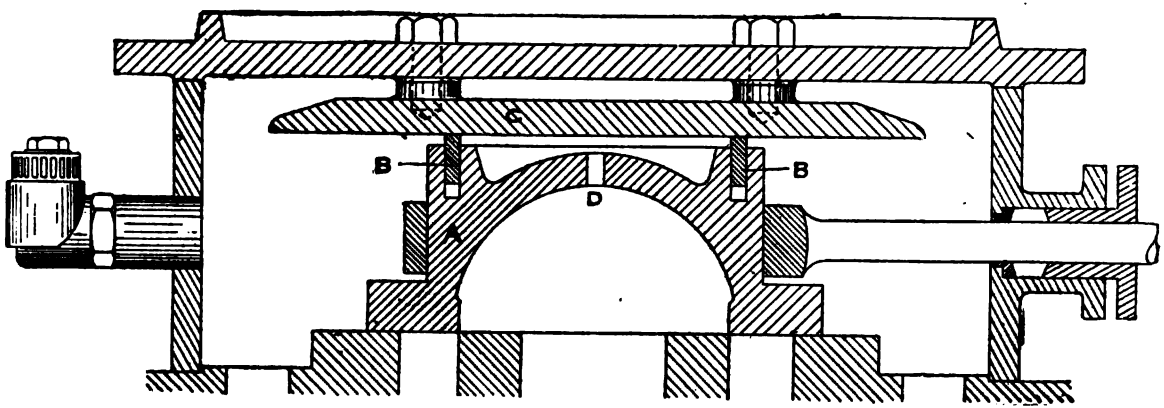


FIG. 4

RICHARDSON (BALANCED) VALVE.

valve, BB are packing strips moving freely vertically for a short distance; these strips are supported on springs, which hold them lightly against the pressure plate of the steamchest. Similar strips are arranged across the ends of these strips, thus cutting out a rectangular space on the top of the valve. When steam enters the chest, the pressure works the packing strips up and maintains a steamtight joint, which relieves the area of the valve bounded by the packing strips of any pressure. A port D connects this space with the exhaust cavity and permits all leakage to pass immediately out of the balanced area. This type of packing is very simple and very reliable; it can of course be used on the Allen or any other slide valve.

Fig. 5 illustrates the American Balance, applied to a plain slide valve. A is the valve, B is a round disc, which is bolted to top of valve and has a bevel groove turned in its top face. The bevel edge of this groove carries the packing ring C, which is pressed against the pressure plate D by the steam pressure on the under side. If the valve is large, two discs and two packing rings may be used. An absolutely steam tight joint is claimed for this packing, also a greater area of balance. This type of packing is of course also applicable to almost any kind of slide valve.

The so-called piston valve is simply a slide valve of cylindrical form; it allows of a greater port area and by its construction reduces the clearance between valve and piston. As to its balanced qualities, it is more nearly absolutely balanced under all conditions of service than any type of balanced slide valve. Fig. 6 shows an outline of a piston valve, with inside admission, as

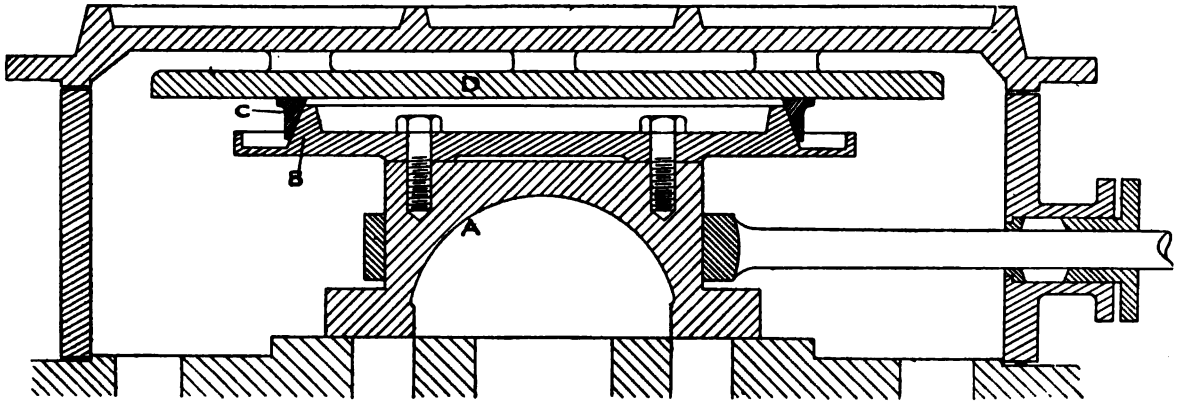


FIG.5

AMERICAN BALANCE, APPLIED TO PLAIN SLIDE VALVE.

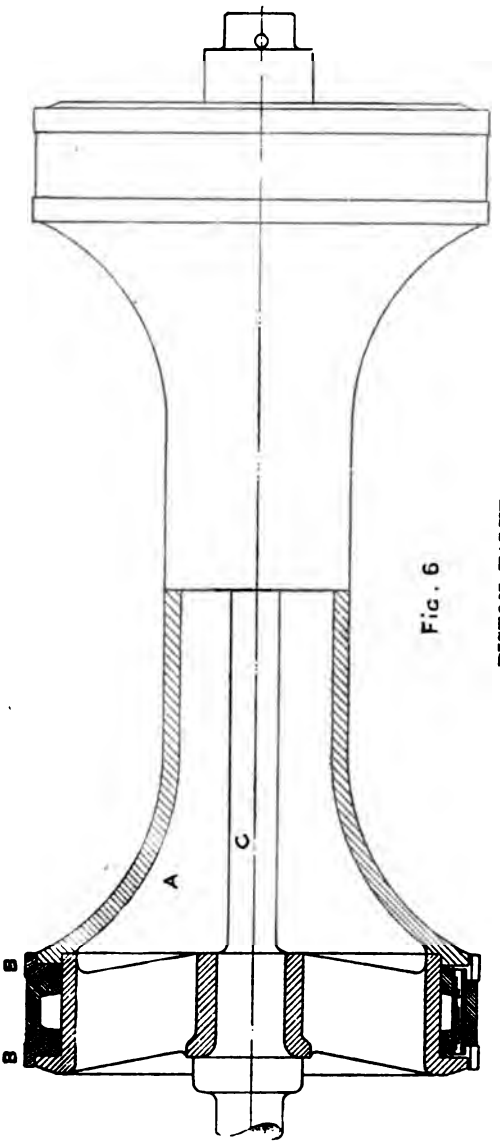


Fig. 6

PISTON VALVE.

made by one of the leading American railways, where A represents the body of the valve, BB the packing rings and C the valve stem.

When a locomotive is drifting along with the steam shut off, a partial vacuum will be formed in the steam chest, causing the valve to chatter and draw cinders and dust into the cylinder and steam chest. To overcome this evil, a relief valve is usually used in addition to the regular steam chest pressure relief valve, which admits air into the cylinder when the steam is cut off.

The Link Motion is the device to regulate and reverse the motion of the valve. There are many designs of Link Motions, but the ones mostly used may be reduced to a very small number. The Stephenson Link Motion is the one most commonly used in America and it has remained practically unchanged since its invention. It is acknowledged to be one of the best reversible valve gears in existence at the present day.

An outline illustration showing the arrangement of the Stephenson Link Motion is shown in Fig 7, which illustrates the usual form of direct motion as used on American locomotives.

The forward and back-up eccentrics are keyed to the main axle, their centers being F and B respectively. Around the eccentrics are the eccentric straps, which in turn are bolted to the eccentric rods; the forward rod is attached to the top of the link, and the back-up eccentric rod to the bottom of the link. The valve is connected to the top arm of the rocker by the valve rod; the lower rocker arm is attached to the link block, which slides freely in the link. In the middle of the link is the so-called saddle, also forming the pin supporting the link and eccentric rods; the

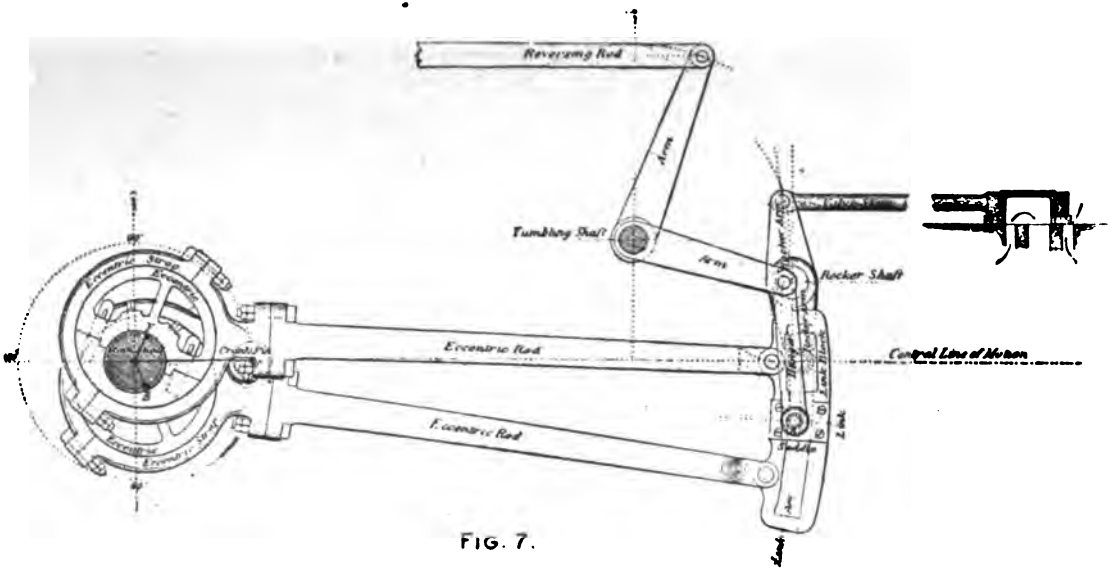


FIG. 7.

STEPHENSON LINK MOTION.

saddle pin is connected with the lower end of the link hanger, while the upper end of the hanger is fastened to one arm of the reversing or tumbling shaft. The other arm of the reverse shaft is connected to the reverse lever by the reversing or reach rod. In the illustration the link is shown to be in full forward gear, thereby allowing the forward eccentric F to control the valve motion. Moving the reverse lever, and by it the reversing rod, so that the pin of the back-up eccentric rod is on a line with the lower rocker arm, will let the back-up eccentric govern the valve motion. By placing the reverse lever in any position between full gear and the center notch of the quadrant, the predominant influence on the motion of the valve of one eccentric over the other can be regulated at will. The valve travel at the same time will be reduced as the reverse lever is moved toward the central position on the quadrant.

The distinguishing difference between an indirect and a direct valve motion is at times confusing. For the Stephenson motion the rocker arm is the guide to a proper classification. The usual form met with in America is the indirect; that is, the forward motion of the link is reversed through the lower and upper arms of the rocker, thus imparting a backward motion to the valve. If, however, the two arms of the rocker are both extending upward or downward the motion would be direct. This form is usually met with in cases of engines having piston valves, when the steam ports are so arranged that the engine takes steam from the space between the two rings or ends of the valve.

There are many things to be considered in the laying out of a Stephenson Link Motion. Those

which influence the valve's travel are angularity of the main rod, the vertical distance between the center lines of the cylinder and the driving wheels, the back-set of the saddle-pin, the relative position of the reverse shaft and the rocker, the actual length of the eccentric blades and the lengths of the reverse shaft arms.

The angularity of the main rod is noticed in the fact that the crank pin will travel less than the distance from front dead center to the quarter position when the crosshead pin is traveling from front center to middle stroke position. At the same time the crank pin will travel more than the distance from quarter to back center position while the crosshead pin is traveling from middle stroke position to back center position. This inequality of travel is greater as the length of the main rod is reduced. Its effect is to retard the points of cut-off and release in the front end of the cylinder of an engine with indirect valve motion, and to hasten these events in the back end. It at the same time increases the lead in the front end and decreases it in the back end.

The angular vibration, or the crossing of the eccentric rods as the eccentrics are rotated gives the same effect on the valve as the angularity of the main rod.

In this discussion an indirect motion only will be considered and at the same time all statements will refer to a slide valve having, as is usual, the steam admitted by the outside edges. For a direct valve motion or for an inside admission valve the proper corrections will have to be made. The locating of the eccentric blade pins back of the center line of the link arc has directly opposite effects upon the valve than the

angularity of the main rod and the angular vibration of the eccentric blades. A correction of the effects produced by the angularity of the main rod and the angular vibration of the eccentric blades could be obtained by placing the saddle pin ahead of the link arc. The correction of the errors in the valve motion due to the eccentric blade pin being placed back of the link arc center is obtained by placing the saddle pin back of the link arc center. The final offset of the saddle pin is the resultant of these two correcting measures.

Very few locomotives are built with the center line of the cylinder passing through the center lines of the driving wheels. The effect of this is to introduce an irregularity in the effect produced by the angularity of the main rod. The effect produced in the forward stroke of the engine will be different from that produced in the back stroke, but within reasonable limits this will not give bad results. If, however, the vertical distance between the center lines of the cylinder and the axles becomes too great, the only remedy is to incline the cylinder so that its center line will pass through the center line of the main driver.

The points so far considered refer only to the matter of obtaining equal cut-offs. As mentioned, this is finally obtained by locating the saddle pin so as to compensate for all the other irregularities. This pin is usually located by actual trial, either on the engine by the use of a slip saddle or on a full-sized valve motion model.

The locating of the tumbling or reverse shaft and the length of the link hanger are details which affect the lead. These two items are ones which

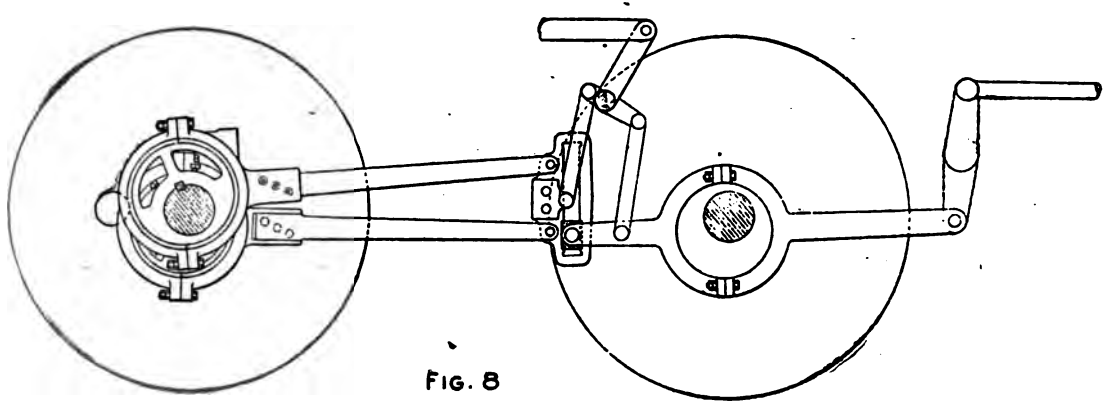


FIG. 8

ALLAN LINK MOTION.

have to be investigated on the drawing board, the aim of the design being to obtain equal lead.

There are, of course, many points to be considered in setting the valves of an engine with the Stephenson Link Motion. After finding the dead centers and marking the port marks on the valve stem, the first step is the equalization of the cut-offs and the lead. It must be noted, however, that both these items cannot be perfect at the same time. If one is equalized all around, the other is not. Usually for engines in road service the back gear is sacrificed to help the forward gear.

To equalize the valve events for the different strokes, the eccentric blades are lengthened or shortened. Raising or lowering the link or the link block is done to equalize the two sides of an engine. To alter the amount of lead, the eccentric is shifted on the axle. One of the peculiarities of the Stephenson Motion is that the lead increases as the cut-off is decreased. By some this is claimed to be an advantage and by others a detriment to good steam distribution. However, in setting valves the general practice is to make the lead a certain desired amount for the ordinary running conditions and cut-offs, and sacrifice, if necessary, the good motion under the extreme conditions.

The Allan Link Motion was invented and patented many years ago by Alexander Allan, of England. Its application to some locomotives of a well-known American railway is illustrated in outline in Fig 8. This is of the form known as Straight Link Motion, where all the locations of the link block lie in the same straight line. Link motions of this form give a practically con-

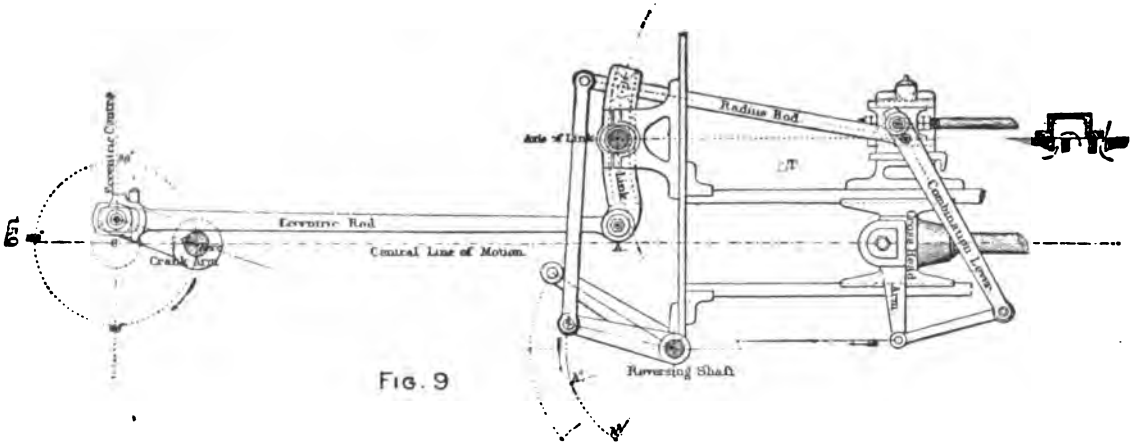


FIG. 9

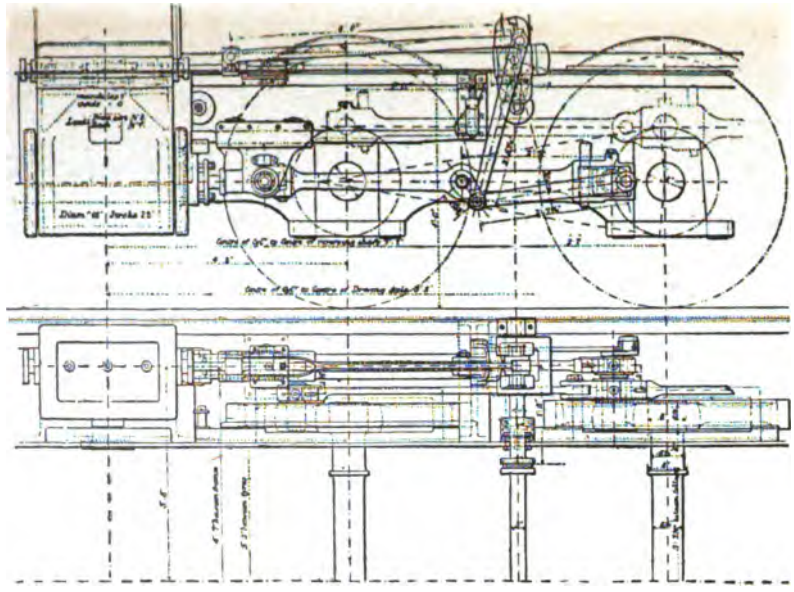
WALSCHAERT LINK MOTION.

stant lead when well designed and it is claimed that "the slip of the link" is greatly reduced.

In Fig. 9 is shown a diagram of the Walschaert Link Motion. No eccentrics are used in this form, but an arm on the main crank pin gives the valve part of its motion. The link rotates about a fixed axis, the radius of its arc equaling the length of the radius rod. This rod is raised or lowered by the arms of a reversing shaft, from one full gear position to the other. It is evident from the diagram that the forward is an indirect, while the backward is a direct valve motion. The cross-head motion is connected to the eccentric motion through the combination lever, and by this means the valve is enabled to maintain both a constant lap and lead. This motion is receiving considerable attention and there are many applications of it being made.

The Joy valve gear, like the Walschaert, also dispenses with eccentrics and gives motion to the valve from the connecting rods through a system of levers. Some of the advantages claimed for this valve gear are: That the cut-off and the lead are exactly equal in both ends of the cylinder, and remain so for all grades of expansion; that the motion admits of prompt cut-off and exhaust release, while it moves the valve slowly during the expanding and exhausting periods; that its construction is simpler and it is easier of maintenance. Its application to an outside connected locomotive is shown in Fig. 10.

The Stevens Valve Gear as used somewhat extensively by a prominent Pacific Coast railway, is shown diagrammatically in Fig. 11. But one eccentric is used to operate the valve; the opening of the ports being controlled by the eccentric,



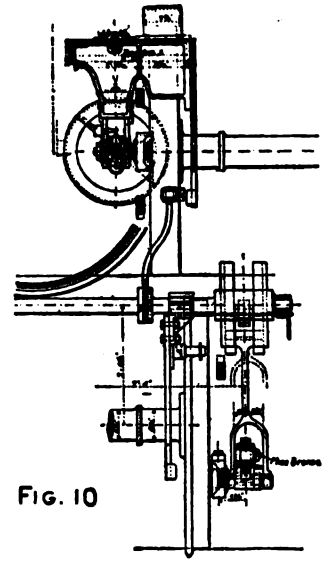


FIG. 10

JOY VALVE GEAR.

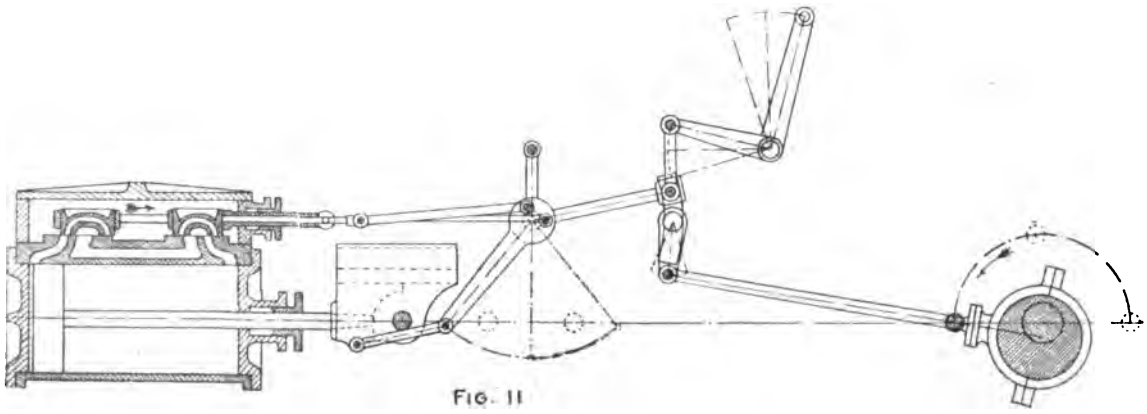


FIG. 11

STEVENS VALVE GEAR.

while the lap and lead are derived from the cross-head motion. The valve opens sharply for admission until the port is wide open, then remains almost stationary and finally closes again rapidly. The reversing and adjustment of the cut-off are obtained by moving the block in the curved link, which is pivoted on a fixed center, about which it is make to oscillate by means of a single eccentric rod. This gear is very similar in detail to the Walschaert, the only marked difference being the use of two valves in each chest.

CHAPTER IX.

COMPOUND LOCOMOTIVES—INTRODUCTORY.

NOTE—In regard to the merits of the compound cylinder as compared with the single-expansion, I do not desire nor profess to express any opinion. I merely wish to describe the compound cylinder in what follows, and, if in some places preference seems to be expressed, it is the claim of builders and not mine. Those who use locomotives must themselves be the judges of the respective merits of single-expansion and compound cylinders and of the particular pattern they want.

M. M. K.

In view of the fact that the Compound Locomotive is of comparatively recent introduction as compared with the single-expansion cylinder, its construction and working are less understood by those connected with the equipment department of railroads. These particulars I have, for that reason, thought it best to embody here. More and more attention is being given to the expansive use of steam in connection with the locomotive. It is claimed not to be unreasonable in view of the triple and the quadruple expansion of steam (expansion in three and four cylinders) in the most approved stationary and marine engines that it should be possible to devise practical means of obtaining double expansion, at least, in a locomotive. Because of the more or less gen-

eral introduction of compound cylinders, some account of the working of the compound locomotive is becoming every day more and more necessary to those connected with the machinery and equipment of railroads. Indeed, practical familiarity with the working of compound engines may be said to have become, in a measure, a necessary part of the knowledge of every engineer and firemen, for the reason that their duties may at any time, through promotion or otherwise, take them to roads where some form of compound locomotive is extensively used. Moreover, it is well that their attention be especially directed to the subject in order that it may have the consideration and scrutiny at their hands which its growing importance justifies and their practical knowledge is likely to render so valuable.

It is not surprising, inasmuch as the opinions of engineers and firemen respecting the operation of simple engines differ so widely, that there should be much controversy among them in regard to the operation of compound locomotives. Experience on the part of those operating the compound locomotive will tend to its better service and consequently greater development. Many prejudices against it are due to lack of acquaintance with its operation. This is true of every new thing. Especially is it true in the case of compounds where a railway has few locomotives of this kind. The feeling is but natural, if we remember, as we should, that in the handling

of their engine the reputation of the engineer and fireman is at stake. The opportunity afforded them for handling and studying any odd engine, compound or otherwise, is necessarily limited. Moreover, in the operation of such locomotive, it is possible they may be impressed with the unhandy, because unusual, cab arrangements. Naturally, they are filled with apprehension, lest some accident might occur and they be found ignorant of what should be done to temporarily repair the engine and bring it in. If a considerable number of the locomotives of a railroad are compounds of similar class, the men handling them become accustomed to their operation and this fear disappears. It is with a view to the practical usefulness these pages may have for engineers, firemen, and others interested in the operation of compounds, that the descriptions herein are elaborated to the extent they are.

The plan followed with each class of compound locomotives is, first, to give a general description of its operation, succeeded by a detailed description of its technical parts. This is done that the reader may, in the first instance, if he desires, learn of the general arrangement of each class without the details, and afterwards, at his leisure, he may apply himself to the particular class or classes that most interest him. Following the description of each class of compounds will be found, in catechetical form, information relating to its operation in case of any ordinary derangement of its parts when the methods of procedure will differ from those in case of similar accidents

to simple locomotives, as outlined in the manual. It is said that reforms must pass through three stages: ridicule, argument, and adoption. The compound has been subjected to the first and second of these epochs, and it may be assumed to have reached the last stage mentioned. Like every part of a railroad, it is still in a state of evolution. I know of no preference in regard to compounds that is proper to express here. The order of description has, therefore, no significance. In the description of the various types I have endeavored to eliminate all matter that does not pertain directly to the practical application of the principle of compounding, as descriptions relating to other parts of the locomotive are to be found elsewhere in "THE SCIENCE OF RAILWAYS." In relation to the descriptions of the compound, I wish to say that I am indebted in a marked manner to Mr. E. W. Pratt, whose familiarity with the construction and working of locomotives and the appliances of the latter makes him an authority of the highest order in regard to all such matters. I am indebted to him in many other ways and it affords me much gratification to be able to acknowledge it thus conspicuously.

CHAPTER X.

COMPOUND LOCOMOTIVES—GENERAL DESCRIPTION—COMPARISON WITH SIMPLE LOCOMOTIVES.

A compound locomotive is one in which the exhaust from one or more cylinders is passed into one or more other cylinders and made to do more work by further expansion before it is allowed to escape to the atmosphere. In stationary and marine service the principle of compounding has long since passed its experimental stage and, following the replacement of the single-expansion engine by the double-expansion type, came the era of high boiler pressures with triple and even quadruple-expansion engines in marine service. It was long thought by many, and is still held by some, that, although compounding of steam in marine and stationary engines was a great economy due to the use of the condenser,* on locomotives where condensers were impracticable, the compound locomotive would not be able to gain sufficient advantage over the simple engine to warrant its general use.

Without any attempt to pass judgment upon the relative value of the points put forward for and against compound locomotives, I will out-

*A condenser is a chamber into which the final exhaust of an engine takes place and in which the steam is cooled and condensed, either by a jet of water or by contact with sheets or tubes having cold water circulation on their opposite sides. These two forms of condensers are termed "jet condenser" and "surface condenser," respectively.

line some of the claims made by their advocates and also some of the practical objections met with in their use, many of which objections have been largely overcome in the later designs.

It should be remembered that the locomotive is not a steam engine merely, but consists of a boiler as well, and must also carry water and fuel for its own demands.

The first advantage of the compound over the simple locomotive comes from its greater economy in fuel, resulting primarily from the saving in steam. There is, however, a secondary saving, produced by the less violent effect of the exhaust upon the fire and also the economical use of high boiler pressures in compound engines.

Experiments have shown that high boiler pressures, say above 180 pounds, which have been found very economical (especially in the space occupied per horse power developed) in stationary and marine engines, are not a source of economy with the type of single-expansion locomotives in use in this country, due to the extreme ranges of temperature within a single cylinder and the consequent condensation. Also, locomotive cylinders and their steam ports are not well protected, and compounding the cylinders renders the variations of temperature in each cylinder less wide, and thus makes practicable the use of higher pressure. With the use of steel in place of iron for boiler construction, and also on account of the excellent care and inspection given all locomotive boilers, there is no material increase of first

cost or for maintenance of high-pressure boilers. In simple locomotives the exhaust produces such a violent draft upon the fire that great quantities of unconsumed fuel are drawn from the fire-box and thrown from the stack. This is not alone a waste of fuel, but cinders entering the open car windows are a source of great annoyance to passengers, while, before the use of the compound locomotive in the service of suburban railways, the noise of the exhaust had to be overcome by means of mufflers, which became quickly choked up and produced a high back-pressure on the pistons, resulting in the loss of from 15 to 20 per cent. of the power.

The throwing of sparks from the stack is not only a source of annoyance, but frequently results in heavy losses from damage by fire in timber and agricultural districts, and this is largely, if not entirely, overcome by the compound locomotive.

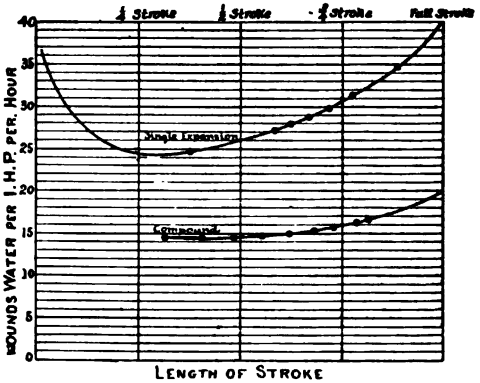
The heating surfaces of any given boiler absorb heat from the fire and deliver it to the water at a certain rate. If the rate at which the products of combustion are carried away exceeds this rate of absorption, there will be a continual waste that can only be overcome by reducing the velocity of the products of combustion. In the compound locomotive this is effected by the milder exhaust. It has been clearly demonstrated by experiment, that a milder exhaust and consequently a slower rate of combustion produces a greater evaporation of water per pound of fuel.

The milder exhaust is, of course, the result of a

lower back-pressure and thereby permits a greater effective power on the piston.

There is also found to be considerable reduction in cylinder condensation, owing to the relatively small variation of temperatures in each cylinder as compared with single-expansion engines. In any engine the walls of the cylinder, one cylinder-head, and one side of the piston are cooled to the temperature of the exhaust steam during each stroke, and the live steam, again entering, must

Fig. 1.



reheat them to its own temperature, thus condensing and requiring additional steam to flow in and take its place. In the compound this total range of temperature is divided between the high and the low-pressure cylinders, and thus the variation and consequent condensation in each cylinder is less.

The saving of steam results in the saving of

both water and fuel. The economy in fuel can be directly reduced to dollars and cents, while that resulting from the saving of water is more indirect. In bad water districts, the reduction of from 15 to 20 per cent. in the amount of water used, necessitates less frequent washings-out of the boiler and must result in greater life and diminished repairs to boiler and flues. Moreover, as its carrying capacity of water limits the distance that a locomotive can run without stopping (or slowing up, where track-tanks are used), it is evident that the compound locomotive would have an advantage in this respect. Fig. 1 besides showing the most economical point of cut-off for simple and compound engines, as far as the use of water is concerned, clearly shows the relatively smaller amount of water used by the compound per indicated horse power.

No locomotive can haul more than its adhesion to the rails will permit, and hence the tractive power of an engine is based upon whatever the adhesion to the rails may be. This is determined by practical experiment. With a fairly dry rail, a turning force of more than one-fifth, or 20 per cent., of the weight of the drivers on the rails, will cause the wheels to slip; a perfectly dry rail will permit of a tractive power of about one-fourth, or 25 per cent., of the weight on the drivers; a well sanded dry rail will allow one-third, or 33⅓ per cent., while a bad frosty rail will permit less than half this last amount. Where all the driving wheels are connected, it matters not, of course, whether this force is ap-

plied by one or many cylinders, but, if the power is not uniformly distributed throughout the revolution and becomes sufficiently excessive at any one point to cause the wheels to slip, a very much less power will thereafter keep them slipping. It is a well known fact that adhesion, and consequently the tractive power of a locomotive, is very much reduced after the wheels begin to slip.*

It is claimed for the compound, that, as the average cut-off is later in both cylinders than for simple engines, the turning power is more uniform throughout the revolution, and hence heavier trains can be hauled than with the single-expansion engine. Then, too, while it would be uneconomical at other times to design a simple engine with cylinders sufficiently large to develop so high a tractive power as 33⅓ per cent. at slow speeds, this can be done with compound locomotives of the "convertible" type without loss in economy under ordinary speeds of service, when working compound.

A saving of oil has been one of the minor economies claimed to be incidental to the use of compound locomotives. It is generally thought that from six to ten drops of valve oil per minute are required to be supplied with the steam in order to properly lubricate a valve and cylinder. This

*Every engineer knows this and puts his knowledge into practice when on a very slippery rail by opening the throttle very slightly and leaving the valve in full gear, thus distributing the pressure more uniformly throughout the stroke than would be the case with a shorter cut-off.

oil is supplied to the high-pressure cylinder only, and hence, in the two-cylinder class of compounds, a saving has been effected in many cases.

Comparative tests of greater or less duration have been made by various railways, between compound and simple locomotives of otherwise similar construction, and the results obtained by the different experimenters are widely at variance. In general, it may be said that the reported saving in fuel with the compound is about ten per cent. in fast passenger and 20 per cent. in heavy freight service, although figures double the latter have frequently been given.*

Later designs of compound locomotives, arranged to be worked simple at the will of the engineer, will temporarily pull a heavier train than a simple engine of otherwise like design. When it is considered that the ruling grade on a division is the governing factor for the maximum rating of through trains over the whole division, it will be seen that a locomotive capable of enough greater power to haul an additional car or two up that grade, produces more economical service for the whole division.

Leaky valves and cylinder packing are less wasteful in a compound than in a simple engine. Steam leaking by the valve or packing of the high-pressure cylinder is still worked expansively

*Fast freight service will more nearly compare with express passenger service and the saving will be less than in heavy slow freight service, on account of the simple engine using steam more expansively in the former service than in the latter. This is more fully brought out elsewhere.

in the low-pressure cylinder. Then, too, the difference of pressure between the two sides of the valves and pistons is less than for simple engines, and the wear should be consequently less.

On the other hand many serious practical objections have been raised. The large cylinders greatly increased the weight of the reciprocating parts.* This must be followed by heavier counter-balance† weights and their accompanying evils.‡ Also larger ports and consequently larger valves must be provided for the large cylinders. Inasmuch as considerable difficulty was formerly experienced in obtaining admission and exhaust ports of sufficient size for the cylinders of large high-speed single-expansion engines, it is not remarkable that there should have been considerable trouble experienced from this source in designing ports for the much larger cylinders of the compound locomotive.

In connection with these last two points, the weight of reciprocating parts and the port re-

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*By the reciprocating parts is meant those parts that have a forward and back (or reciprocating) motion. This includes the pistons and piston-rods, the cross-heads and a certain part of the main rods.

†The counter-balance is the balance weight placed in the wheel at a point opposite the crank pin. (See No. 240, Plate I.)

‡The counter-balance weights act at all points of the revolution, having an outward or centrifugal tendency from the center of the wheel that is great at high speeds, and is only counteracted when the engine is passing the front and back centers. At other points it produces an upward tendency upon the engine when moving up and a downward blow upon the rails when moving down.

quirements, let us see for one moment what the requirements for high speed are. Take an engine with a five foot driving wheel and a twenty-four inch stroke, traveling at the not unusual rate of a mile a minute. This requires 336 revolutions per minute, and means that the piston starts and stops 672 times, and with all its stopping and starting travels 1344 feet per minute. At mid-stroke the piston speed is about 35 feet per second or 24 miles per hour. To the average railway man high speeds are so common that I can think of no better way to show the full meaning of these figures than to compare them with those of a falling body acted upon by gravity. A falling body at the end of the first second is traveling at the rate of 32 feet per second, or about 22 miles per hour, and in gaining this speed the body has fallen some 16 feet, through which distance the continued action of gravity has produced this not inconsiderable acceleration, while in the case of the piston of the locomotive in question, the still greater speed of 24 miles per hour must not only be attained by the time the piston has reached the middle of its stroke, or in one foot, but also it must be exerting great additional propelling power on the crank pins. The steam in front of this rapidly moving piston must be exhausted freely or there would be no effective power to maintain the speed. Where the reciprocating parts weigh nearly a thousand pounds, it will be seen what enormous power is required to stop and start them without jar or shock to the locomotive, and also the size of ports required to

freely exhaust the pressure ahead of and freely supply steam behind the very large pistons of compound locomotives. With any of the several types of valve gear used in locomotive practice to-day, it goes without saying that no compound can be relatively so efficient, in comparison with single-expansion engines, in express passenger as in freight service, for the reasons hereinbefore described. When many single-expansion locomotives with moderately large ports require a velocity of steam through their ports of over 1,000 feet per second, it can better be imagined than told what the port requirements are for the large low-pressure cylinder on a compound. It is generally considered that for express passenger service the low-pressure cylinders should not be so large in proportion to the high-pressure cylinders as for freight service.

Many of the earlier compounds in this country suffered in comparative tests with simple engines of otherwise similar design, by having cylinders of too small a size to do the same work as the simple engine. While they did their work with economy, they would not haul the heavy trains of the simple engines, and their supposed capacity had to be reduced, to the annoyance of those engaged in the operating of trains. Since then, with the advent of larger cylinders and the "convertible" class of compounds, the conditions have become altered.

With any locomotive, when steam is shut off, as in running down grade, the pistons act as air compressors, causing thumping, rough riding, and

cooling of the cylinders, as well as a strong draft in the stack at a time when no steam and little draft are required, and thus produce a waste of fuel. The large low-pressure cylinders of the compound have greatly magnified this evil, and several builders have overcome it by the use of automatic valves on the low-pressure cylinder, by which the two sides of the low-pressure piston are connected whenever the locomotive is drifting.

After closing the throttle, an engine working compound will make several strokes before all steam is finally exhausted. This delay in clearing the cylinders of steam, placed compound locomotives to considerable disadvantage in switching or like service; also, in such service, accustomed to gauge the speed by the exhaust of the engine, trainmen were often deceived by the less frequent exhaust of the two-cylinder compound. The employment of the separate high-pressure exhaust, whereby the engine can be run simple at the will of the engineer, it appears, has overcome these objections from an operating standpoint.

Many of the earlier forms of intercepting valves were of the poppet type and hammered badly in opening or closing. It will be noticed that these valves in the later designs are of the piston type and are almost invariably cushioned by dash-pots connected thereto, or some other equally effective means.

It is also claimed that the breakage and loosening of the large low-pressure cylinders have been considerably done away with by the use of proper

reducing valves and a better attachment of cylinders to the frame, the use of double front rails for the latter being particularly noticeable in modern construction of large locomotives.

Thus it is that improvements in design and construction are continually taking place, and the upholders of the great principle of compounding will certainly witness their more extensive adaptation to all classes of service.

CHAPTER XI.

CLASSES OF COMPOUND LOCOMOTIVES AND THEIR GENERAL CONSTRUCTION—DIFFERENT TYPES.

There are many classes of compound locomotives in use. First, the *strictly plain compound,* where no live steam is admitted to the low-pressure cylinder, even in starting. The Webb three-cylinder compounds (with cylinders arranged as outlined in Fig. 6,) which are usually without connecting rods—the two high-pressure cylinders turning the rear pair of driving wheels by two outside cranks while the low-pressure cylinder turns the forward drivers by means of an inside crank—belong to this class and are used in considerable numbers on the London & North-Western of England. They are not powerful in starting, as the driving wheels acted upon by the high-pressure cylinders must turn, either by slipping or moving the train, before steam enters the low-pressure cylinder.

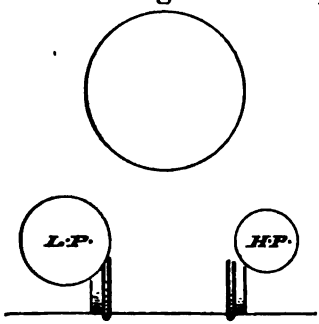


Fig. 1.

Second, *automatic compounds*—those using live steam in the low-pressure cylinder in starting only, automatically changing to compound with the first stroke, and thereafter cannot be run except as compounds.

The third class can be run simple or compound at any time at the will of the engineer and will be termed *convertible compounds.*

Each of these principal classes may have two, three, or four cylinders. The two-cylinder or "cross-compound" always has an intermediate receptacle. called a receiver,* between the high and low-pressure cylinders, while the four-cylinder engines may or may not have receivers — those with both pistons attached to the same crosshead generally have not. The three systems of four-cylinder compounds used in this country are the Baldwin (Vauclain), the Brooks (Player), and the Johnstone. Of these, the Brooks has receivers, while the remaining two are of the continuous expansion† type and have no receivers.‡

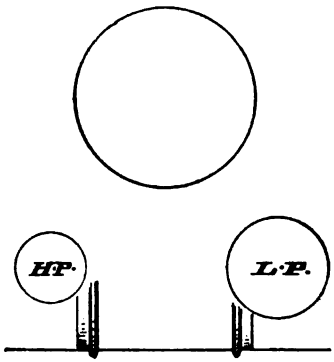


Fig. 2.

*The receiver is for the purpose of receiving the exhaust from the high-pressure cylinder and holding it until the engine gets to the point in the revolution where it is admitted against the low-pressure piston. Incidentally, the receiver may act as a reheater, if located in the smoke-box, as is usually the practice.

†Meaning expansion without any pause or interruption as is the case when a receiver is interposed between the high and the low-pressure cylinders.

‡In Europe the Hungarian State Railways employ four-cylinder tandem compounds with one receiver into which both high-pressure cylinders exhaust and from which both low-pressure cylinders receive their supply.

The arrangement of cylinders is quite varied, as shown by the several skeleton cuts. There may be two cylinders, one high-pressure and one low-pressure, as outlined in Figs. 1, 2 and 3, one high and two low-pressure, as in Figs. 4 and 5; two high-pressure and one low into which they both exhaust, as in Fig. 6; two high, each exhausting independently into a low-pressure cylinder on the same side of the engine, shown in Figs. 7, 8, 9 and 10; or two high exhausting into a common receiver from which both low-pressure cylinders draw their supply, as in Figs. 11 and 12. Aside from the varied arrangement of cylinders, many of the European designs employ three and four cranks and use no side rods. Some French constructions, retaining the use of side rods, employ for the high-pressure cylinders two inside cranks on one driving axle at an angle with the low-pressure cranks on a second driving axle, the angle between the cranks being such as to

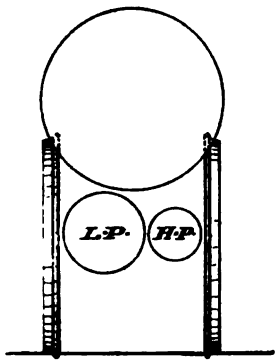


Fig. 3.

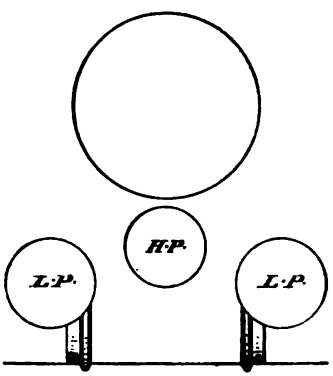


Fig. 4.

give as large a turning power as possible, for all portions of the revolution.

It is, perhaps, needless to say that the wide variations in the service of American locomotives demand that they have a large starting power at all points of the stroke. To obtain this starting power, all the earlier designs used a device called an intercepting valve that, if closed in starting, cut off communication between the receiver and the low-pressure cylinder and at the same time admitted live steam to the low-pressure side, but after the first exhaust from the high-pressure cylinder to the receiver took place, the pressure in the latter automatically shoved open the intercepting valve and simultaneously shut off the further supply of live steam to the low-pressure cylinder. Hence these engines belong to the automatic class of compounds.

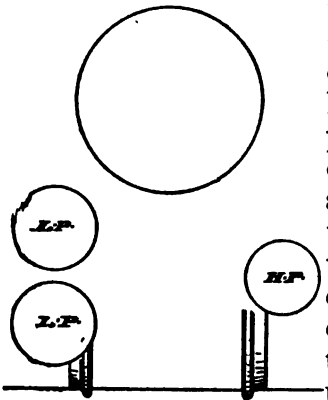


Fig. 6.

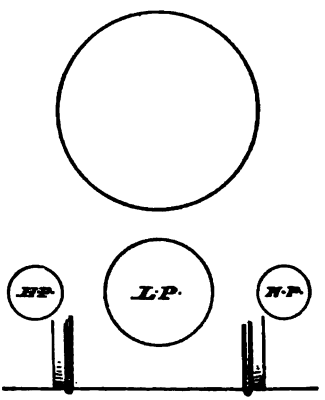


Fig. 6.

Mr. Anatole Mallet, who was the designer of the first practical compound locomotives in Europe

in 1876, was also the first to devise a means by which a compound could be worked as a simple locomotive for any desired period at the will of the engineer. This was accomplished by adding a separate exhaust valve through which the exhaust from the high-pressure cylinder could escape to the atmosphere without accumulating in the receiver. This relieved all back pressure on the high-pressure piston and admitted of greater power at slow speed than was otherwise obtained.*

Many objections were raised to placing the operation of the engine either as a simple or as a compound in the hands of the engineer, and the fear was freely expressed that the average engineer would run the locomotive to its disadvantage in simple position more than enough to offset the saving when operated as a compound. However, one prominent railroad officer, in placing the operation of the valves at the will of the engineer, seemed to express the now settled conviction of all, when he said: "To argue that an

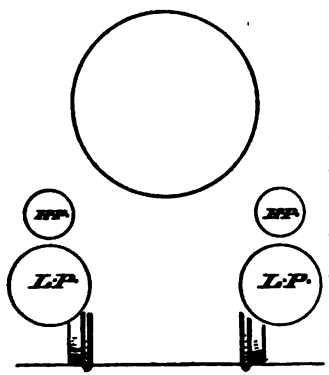


Fig. 7.

*It should also be stated that not only were the automatic compounds less powerful, at slow speeds after starting, than simple engines, but, except in the case of four-cylinder engines having one high and one low-pressure cylinder on the same side they were practically helpless in case of a broken steam chest on either side. The use of the separate exhaust valve has greatly altered the conditions in these cases.

engineer is likely to work simple any longer than absolutely necessary, is about the same as saying that an engineer with the ordinary engine cannot be trusted to pull the reverse lever up as soon as possible."

Later practice interposed, within or near the intercepting valve, a reducing valve, which is used to admit live steam, at a reduced pressure only, into the low-pressure cylinder when starting or when working simple. This reduced the abnormal shocks that were produced when starting large compounds of earlier design. The reducing valve, the intercepting valve, and the separate exhaust valve were so closely combined in many cases and so dependent, one upon the other, in their operation, that it became the tendency among railway and mechanical men to refer to the whole mechanism simply as the "intercepting valve."

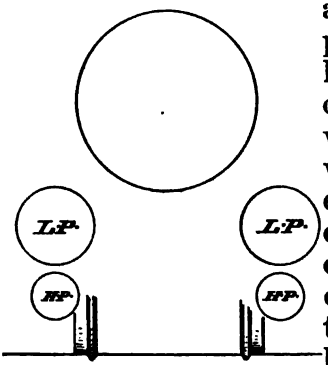


Fig. 8.

While the limit to the size of the ordinary locomotive may be considered to have been reached when the largest practical boiler that can be placed on a given gauge track has been attained. the limit to the American two-cylinder, or cross-compound, with outside cranks will be the maximum width allowable for locomotives. However, again Mr. Mallet, the father of the present era

of compound locomotives, has seemingly solved the problem by dividing the low-pressure cylinder into two cylinders, as shown in Fig. 5, of smaller size attached to the same crosshead. With such a construction it would appear that the boiler would still be the limiting feature of the size of the compound as well as the simple locomotive.

The proper cylinder ratio of compounds for all varieties of service is still somewhat undetermined. By the cylinder ratio is meant the proportion between the volumes of the high and the low-pressure cylinders, not including the clearance

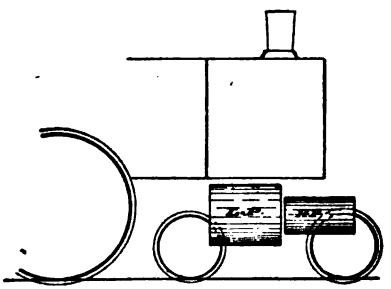


Fig. 6.

spaces. In American practice where the length of stroke is the same, the cylinder ratio would be as the areas of the two pistons, and it can readily be found by multiplying the diameter of each cylinder by itself and comparing the two products. For instance, to find the cylinder ratio of an engine with a 20 inch high and a 30 inch low-pressure cylinder, multiply 20x20 equals 400; 30x30 equals 900; 400 goes in 900 two and one-fourth times, which is the cylinder ratio.

The early practice in this country with two-cylinder compounds gave a ratio of two to one or even less, but extended experiment has demonstrated that a greater proportion than this is advisable and many compounds of this class have a low-pressure cylinder from two and one-half to two and three-quarters times larger than their high-pressure cylinder. The Baldwin works used a ratio of 3 to 1 in their Vauclain four-cylinder compounds for both passenger and freight service for a number of years and consider the results eminently satisfactory, while the builders of the Brooks tandem four-cylinder compound advise a ratio of between 2.8 and 3 to 1. However, the whole problem of cylinder ratios for compound locomotives is based upon the desirability of dividing the work as equally as possible between the high and the low-pressure cylinders, and without going into details, it is apparent that no given ratio will keep the work equally divided

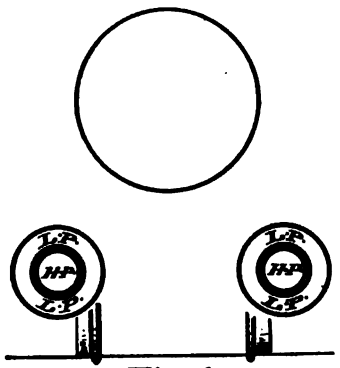


Fig. 10.

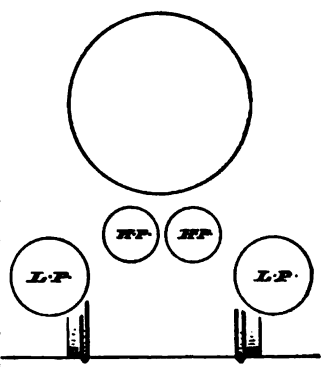


Fig. 11.

for different service and different points of cut-off, nor should this equal division of power between the cylinders be given anything but secondary consideration in comparison with the total economy of the locomotive. To partially equalize the power of compounds, the amounts of lap and lead are not the same for both cylinders; one builder uses a separate lever in the cab for independently adjusting the travel of the low-pressure valve, as fully described elsewhere.

There seems to be no general rule followed by builders in this country as to which cylinder of a two-cylinder compound should be placed on the right-hand or engineer's side of the engine. Generally the intercepting valves are located on the engineer's side to make their connections as simple as possible, and hence, according as the design contemplates the placing of this valve adjacent to the high or the low-pressure cylinder, that one is placed on the right-hand side. But even this rule is not without exception.*

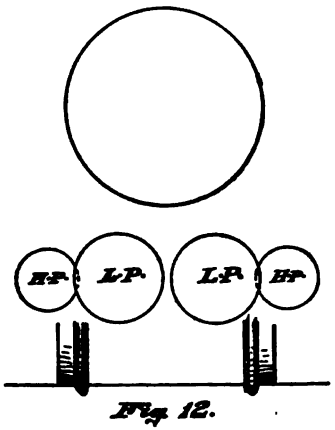


Fig. 12.

*It would seem as though the intercepting valve, if placed between the high-pressure cylinder and the receiver, would cause less wire-drawing of steam to the low-pressure cylinder than if located between the latter and the receiver.

Some compounds have cylinder casings both of the same size, but with the advent of the thirty-four or thirty-five inch low-pressure cylinder it seemed to many advisable to place it on the engineer's side with the thought of its better protection from damage if within his vision, and, furthermore, that the high-pressure cylinder casing be made no larger than necessary for reason of its better protection from accident.

It is becoming the general practice on compounds of any size to place combination safety and relief valves on the receiver and the low-pressure chest and cylinder heads to avoid damage in case of broken reducing valve or other accident that might produce unsafe pressure on that side.

THE BALDWIN FOUR-CYLINDER COMPOUND.

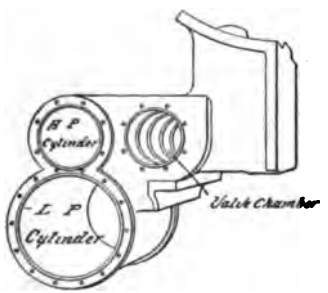
The builders of the "Vauclain" four-cylinder compound locomotives claim a design productive of the greatest efficiency with the utmost simplicity of parts and the least possible deviation from existing practice; that they also develop equal power on each side of the locomotive, thereby preventing the racking of the machinery resulting from an unequal distribution of power; and that, in their method of handling by the engineer, there is but slight departure from that of single-expansion or non-compound locomotives. They may be started, and run for any desired length of time, either simple or compound, at the will of the engineer, and can be changed from the one to the other at his discretion by the

movement of a small lever in the cab which also operates the cylinder cocks.

The principal features of construction are as follows:

The cylinders consist of one high-pressure and one low-pressure cylinder for each side, the ratio of their volumes being as nearly 3 to 1 as the employment of convenient measurements will allow. They are cast in one piece with the cylindrical valve chamber and the saddle, the cylin-

Fig. 13



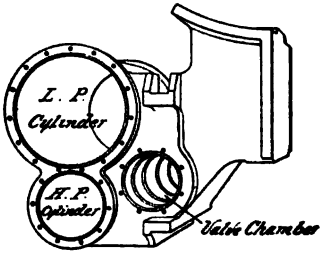
Baldwin Four-Cylinder Compound.
Cylinder Arrangement

ders being placed one directly above the other and as close together as they can be with adequate walls between them. Figs. 13 and 14 show the proximity of the two cylinders, while in Fig. 15, which shows the arrangement of the cylinders in relation to the valve, the actual construction is distorted for illustrative purposes.

The valve used to distribute the steam to the cylinders is of the piston type, working in a cylindrical steam chest located in the saddle of

the cylinder casting as close to the cylinders as possible and between them and the smoke-box, as shown in the figures. This chest, having steam passages cast larger than required, is bored out enough larger than the diameter of the piston valve to permit the use of a hard cast iron bushing. Fig. 22 shows this bushing and one method of forcing it into place so that steam tight joints will be had between all ports; it

Fig. 14.



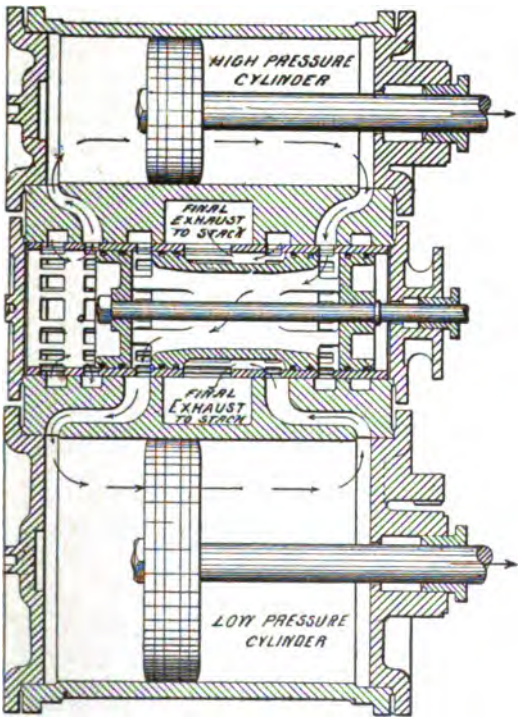
Baldwin Four-Cylinder Compound.
Cylinder Arrangement

also shows the narrow bridges across the steam ports which prevent the eight packing rings of the valve (shown in Fig. 16) from entering the ports. These cast iron packing rings form the edges of the valve.

The valve is of the piston type—double, and hollow between the two inside pistons—but having two solid ends, as shown by Fig. 16, and controls the admission and exhaust of both cylinders. The exhaust steam from the high-pressure

cylinder becomes the supply steam for the low-pressure cylinder and is transmitted from one side of the high-pressure cylinder to the opposite

Fig. 15.



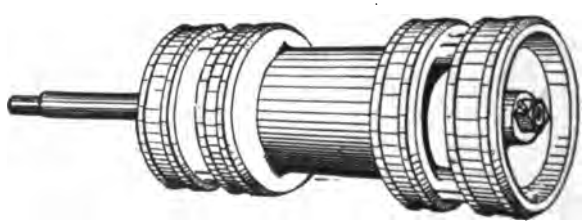
Baldwin Four-Cylinder Compound. Steam Distribution with Piston Valve

side of the low-pressure cylinder through the hollow portion of the valve, as indicated by arrows, Fig. 15. The supply steam for the high-pressure

cylinder enters the steam chest at both ends, thus balancing the valve with the exception of the area of the valve-stem at the back end.

The more common slide valve action being so much better understood by the average railroad man than the piston valve, I will liken this four-piston valve to one slide valve within another having external admission and internal exhaust in both cases. Thus it will be seen that the outside

Fig. 16.



Baldwin Four-Cylinder Compound. Piston Valve.

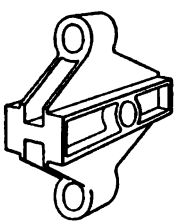
edges of the two outer pistons govern admission and their inside edges the exhaust of high-pressure cylinder, while the two inner pistons similarly regulate the flow of steam to and from the low-pressure cylinder, all of which will be evident by a reference to the arrows in Fig. 15.

Where the front rails of the frame are single bars, the high-pressure cylinder is usually put on top, as shown in Fig. 13, and in that event, with

the usual rocker-arm, indirect valve motion is used.* When the low-pressure cylinder is put above (Fig. 14) on account of the double front rails of the frame, they also prevent the use of the rocker-shaft and box and the valve motion is then termed direct-acting, which necessitates a different location of the eccentrics on the axle.*

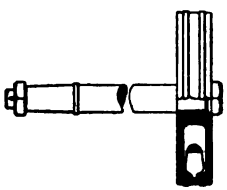
Engineers and those employed in shops and round-houses for setting valves and eccentrics should thoroughly understand the difference between the position of the eccentrics with relation

Fig. 17



Baldwin Four-Cylinder Compound Cross-Head

Fig 18



Baldwin Four-Cylinder Compound Hollow Steel Piston

to the crank-pins for direct and indirect valve motion, as given fully elsewhere in the Manual, and further brought out in the Catechism on Accidents to Baldwin Four-Cylinder Compounds hereinafter contained.

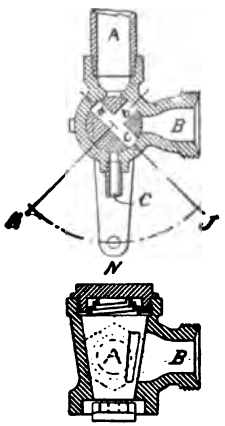
The style of crosshead is shown in Fig. 17. It is made of cast steel, to insure the greatest strength with a minimum weight, the wearing surface being lined with tin. The piston, shown

*Direct and indirect valve motion will be found fully illustrated and explained in the earlier chapters of the Manual.

in Fig. 18, is also preferably made with cast steel heads, the object in both cases being to reduce the weight of the reciprocating parts to a minimum.

It is obvious, that, in starting these locomotives from a state of rest with heavy trains, it is necessary to obtain a greater power than that exerted by the high-pressure piston alone, for there would

Fig. 19



Baldwin Four-Cylinder Compound.
Combined Starting Valve and Drip Cock.

be no pressure on the low-pressure piston until the high-pressure cylinder had made one exhaust; hence it is necessary to admit steam to the low-pressure as well as the high-pressure cylinders. This is accomplished by the use of the starting

valve (Fig. 19).* This is simply a plug-cock which is opened by the engineer by means of suitable levers from the cab, to admit steam from one end of the high-pressure cylinder to the other, and thence, as if it were the ordinary high-pressure exhaust, into the low-pressure cylinder. This same valve acts as a cylinder cock for both ends of the high-pressure cylinder and is operated by the same lever that actuates the ordinary cylinder cocks, which are in this case on the low-pressure cylinder, thus making, probably, the most simple starting device used on any compound locomotive and one not easily deranged. The operation of the starting valve in conjunction with the cylinder cocks is clearly shown in Fig. 20. The starting valve should be kept closed (position *N*) as much as possible, as its indiscriminate use reduces the economy and makes the locomotive "logy."†

Air valves, to prevent a vacuum, are placed in the steam passages of the high-pressure cylinder,

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*This is sometimes called the "By-Pass" valve, as it connects the two sides of the high-pressure piston, but for an entirely different purpose than that to which the by-pass valves are put in connection with the low-pressure cylinder as described hereinafter under the Richmond and the Rogers compound, and for that reason I have not called it a "by-pass" valve. Two earlier forms of starting valves have been used with Vauclain compounds, but, inasmuch as they have been superseded by this form of valve, it is not deemed necessary to illustrate and describe them herein.

†An engine which should be capable of high speed but is not, and in which the pressures work against themselves in the cylinders, is said to be "logy."

a practice now generally followed on all locomotives, either simple or compound. Additional air valves, marked *C* and *C*^{1} in Fig. 20, are placed in connection with the ports in the valve chamber leading to the low-pressure cylinders. Air valves of somewhat different shape have been described and shown in detail heretofore in the Manual.

Water relief valves *W W*, Figs. 20 and 21, which are nothing more nor less than pop valves, are applied to the low-pressure cylinders and attached to the front and back cylinder heads to relieve excessive pressure of any kind, steam or water. The spring in the water relief valves on these engines is made to carry a pressure enough greater than the boiler pressure to prevent their discharging steam and water ordinarily in starting the engine simple.

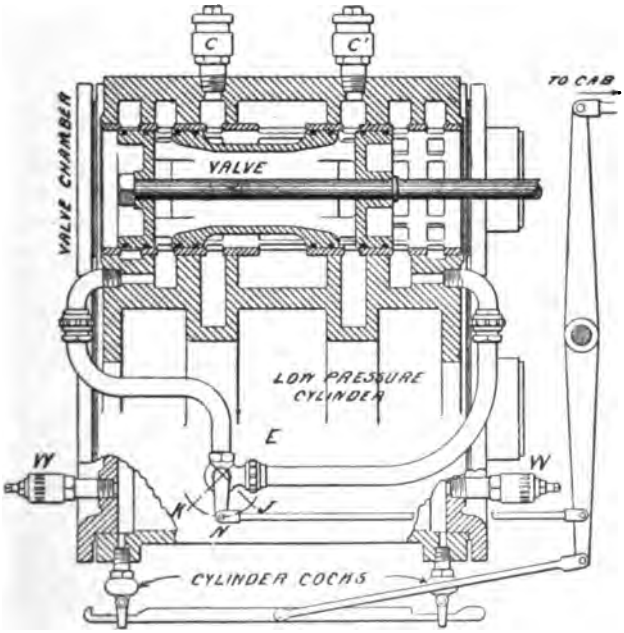
In all other respects the locomotive is the same as the ordinary single expansion locomotive.

Operation of the Baldwin Four-Cylinder Compound.—When starting the locomotive, the engineer should, ordinarily, pull the cylinder cock lever way back and thus open the cylinder cocks in order to relieve the cylinders of condensation, and, as the starting valve is opened by the same movement, steam is thus admitted to the low-pressure cylinder and the locomotive started quickly and freely.

In case the locomotive is at a platform of a crowded station, or in any other place where it is

undesirable to open the cylinder cocks, the engineer should move the starting lever in the opposite direction from that usually given it,

Fig. 20.

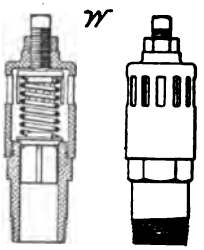


Baldwin Four-Cylinder Compound. Showing operation of Starting Valve and Cylinder Cocks.

placing the starting valve handle in position *J*, Figs. 19 and 20; that is, he should push forward the lever in the cab, thus allowing steam to pass

through the starting valve without opening either the low-pressure cylinder cocks or the drip *C* of the starting valves. By further reference to Fig. 19, it will be seen how, when the handle is in position *K*, ports *A*, *B*, and drip *C* are all connected by the ports *a*, *b*, and *c* of the plug; but if the handle is in the opposite position *J*, ports *A* and *B* only are connected, as *b* is now at *a* and *c* is opposite *B*; in its central position *N* (normal position for compound working), it will be seen that all ports are closed as in the figure.

Fig. 21.



Baldwin Four-Cylinder Compound.
Cylinder Relief Valve

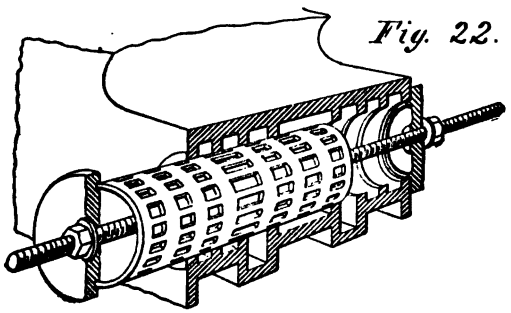
After a few revolutions have been made and the cylinders are free from water caused by condensation or priming, the engineer should move the cylinder cock lever into the central position, *N*, causing the engine to work compound entirely. This should be done before the reverse lever is disturbed from its full gear position.

Ordinarily, the reverse lever should not be "hooked up," thereby shortening the travel of

the valve, until after the cylinder cock lever has been placed in its central position, but it is often necessary to open the cylinder cocks when at full speed to allow water caused by priming or foaming to escape from the cylinders, and in such cases no disadvantage is experienced, and the reverse lever need not be disturbed.

The starting device is simply designed for use in the starting of the train and should not be used at any other time unless there is imminent danger of stalling and the lever has been previously dropped to full gear. In other respects,

Fig. 22.



Baldwin Four-Cylinder Compound Valve Bushing, Showing Method of Pressing in.

aside from these here noted, the rules governing the operation of compound locomotives in general should be clearly understood by any engineer who is liable to be called upon to run a compound locomotive of this or other design.

REPAIRS.

The builders of the Vauclain four-cylinder compound claim an advantage in it over the

two-cylinder or "cross-compound" locomotive in simplicity of parts, there being no intercepting valve,* and a similarity to all the parts of a single-expansion locomotive. Thus its repairs will be similar to those of simple locomotives. To carry out this simplicity of parts, the piston rods of the high and low-pressure cylinders are of the same diameter and designed strong enough to withstand the severest strains of service.

The packing rings in the valves are easily replaced and the valve chest bushing can be cheaply and easily renewed. In extracting old bushings it is best to split them between the ports with a narrow chisel. The new bushings can be pressed in by some such handy device as that shown in Fig. 22.

Accidents to Baldwin Four-Cylinder ("Vauclain") Compounds.—For all ordinary accidents, such as broken main rod or pin, or a broken valve stem, what should be done? The same as for non-compound or simple locomotives, as described fully in the earlier chapters of the Manual.

With a low-pressure cylinder head knocked out, would it be necessary to disconnect that side? Not for a short distance.

In that event, how many exhausts would there be during one revolution? There would be three

*The intercepting valve is the valve which prevents the live steam which is admitted from the boiler to the low-pressure cylinder at certain times, from passing through the receiver to the high-pressure cylinder where it would produce back pressure on the piston.

in the stack and one through the open cylinder head and the latter exhaust might obstruct the engineer's view, if on his side, and render the procedure inadvisable.

With the Vauclain Compound, at what position of the reverse lever is work of the two cylinders most nearly equalized? At a cut-off of about one-half the stroke in the high-pressure cylinder.

When is the work most unequal and the strains on the crosshead consequently the greatest? In starting with the engine working simple, as then the high-pressure piston is nearly balanced by live steam on both sides and the low-pressure cylinder obtains approximately boiler pressure.

What results would be likely should the rigging of the cylinder cocks and starting valve become bent or disconnected? Should one starting valve fail to properly close, the exhausts would be of unequal intensity. If one of them failed to open when required in starting, the engine would be weak on that side as it would have to start compound, that is with steam for the first stroke in the small high-pressure cylinder only.

In this latter event, when would the first exhaust from that side take place? Not until the completion of the return stroke.

If the cylinder cocks open and close with the same rigging as the by-pass valve, why would not the engineer know thereby that the by-pass valve was in position desired? From the previous

description of this rigging, shown in Figs. 19 and 20, it should be remembered that the cab lever pushed clear ahead opens the by-pass valve, but not its drip nor the cylinder cocks.

Before altering the valve motion, what else should be examined if the exhausts were of unequal intensity? Examine for broken packing rings in the piston valve or the low-pressure cylinder.*

In case a valve-stem broke off inside the chest or the valve itself broke, would it be certain of discovery at once, as with an ordinary slide valve? Possibly it would not. Instances have been cited where compound locomotives of this system have hauled passenger trains long distances with broken valve-stems and broken valves. The two ends of the valve being unbalanced by the area of the valve-stem (see Figs. 15 and 16) accounts for the first possibility, while live steam from the induction ports acting on each end of the valve would explain the case of an undetected broken valve.

How can it be found if the cylinder packing in the high-pressure cylinder is blowing? Put the engine on the quarter, block the wheels, and test as usual for leaky slide valve; then, with the starting valve closed (in compound position) and the low-pressure cylinder cocks blocked open,

*A case is cited by the builders where an engineer ran his locomotive two days without any piston head at all in one of the high-pressure cylinders, and even then could not tell what was the matter except that the intensity of the exhausts were unequal and the engine did not make good time. Machinists put to work to locate the trouble, found it to the great surprise of the engineer.

drop the reverse lever into full gear. Steam passing the high-pressure piston will appear at the open cylinder cock of the low-pressure cylinder, but at the opposite end that would be expected with a simple engine.

How can it be found if the packing in the low-pressure cylinder is blowing? Put the engine on the quarter and open the starting valve and cylinder cocks and look for any escape of steam from the low-pressure cylinder cock on the end that should be in exhaust, as with a simple engine.

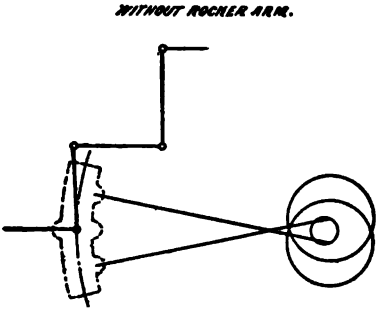
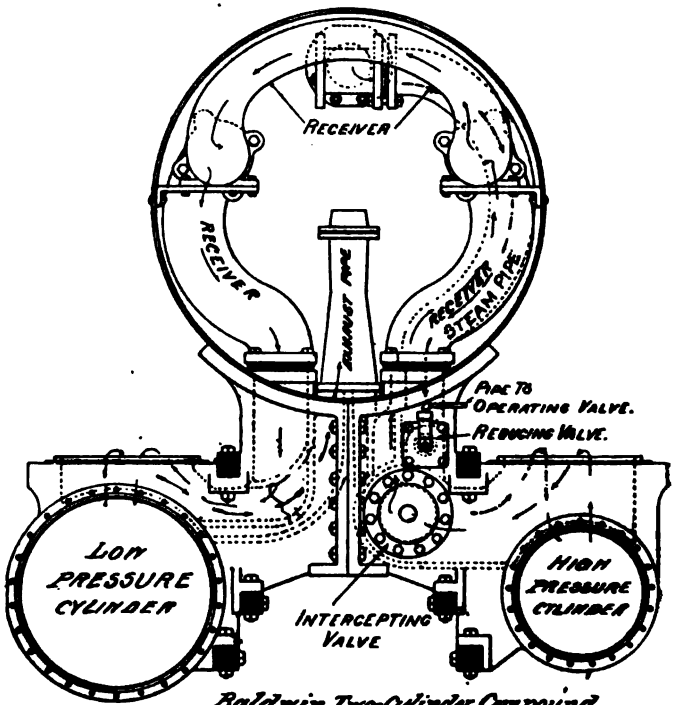


Fig. 23.

With the four-cylinder type, where the large low-pressure cylinder is placed on top, as in Fig. 14, and direct valve motion is employed, how should the eccentric rods on one side stand with the same side of the engine on the forward center? They should be crossed, as shown in skeleton Fig. 23. A slipped eccentric should be set the same as for similar valve motion on a simple engine, as fully described heretofore in the Manual under "Third Examination of Firemen."

THE BALDWIN TWO-CYLINDER COMPOUND.

The original Baldwin two-cylinder compound, built in the year 1892, was of the cross-compound receiver type and, after the first stroke or two,



Baldwin Two-Cylinder Compound

Fig. 24

or as soon as the receiver had attained a pressure of 100 lbs., the engine automatically changed to compound and could not be operated otherwise. It belonged, therefore, to the automatic class of compounds. The reducing and the starting valve

then employed were changed materially in the later design of the two-cylinder compound herewith illustrated and described.

Their later two-cylinder compound locomotives belong to the class of convertible compounds, as they can be operated either simple or compound for any length of time by the movement of a small valve in the cab, as shown by Fig. 28.

Fig. 24 shows a front view, giving the general arrangement of cylinders, steam, exhaust and receiver pipes in the front end, and the location of the intercepting and reducing valve in the saddle of the high-pressure cylinder. The low-pressure cylinder derives all its pressure from the receiver when running compound, as is usual in two-cylinder compounds.

The office of the intercepting valve is two-fold. It acts as an intercepting valve by opening and closing communication between the two cylinders, and also as a separate exhaust valve, by connecting the low-pressure cylinder with the exhaust to the stack. This it does by diverting the exhaust from the high-pressure cylinder either into the atmosphere, when working single-expansion, or into the receiver, when working compound, and is operated at the will of the engineer.

The office of the reducing valve is to admit live steam at a reduced pressure into the receiver and thence to the low-pressure cylinder, when the engine is working single-expansion, and also to close simultaneously with the changing of the intercepting valve to the position which causes

the engine to work compound, so that the receiver will obtain no live steam from boiler when taking the exhaust from high-pressure cylinder. The performance of the first above-mentioned function—that of reducing the pressure of live steam delivered to the receiver—is necessary in order

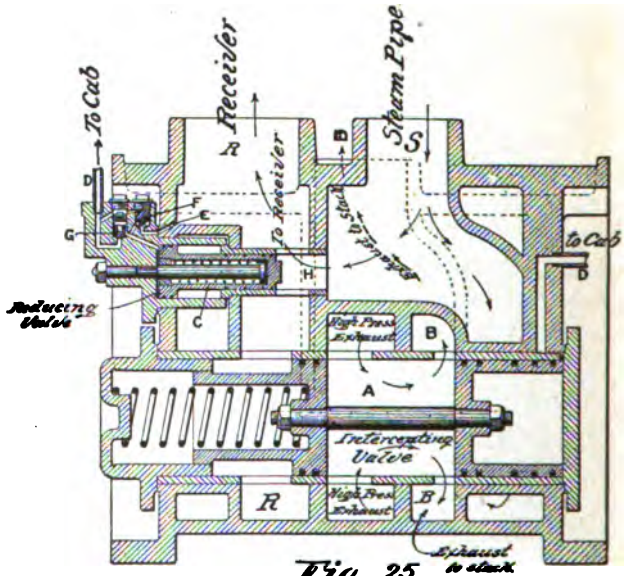


Fig. 25.

Baldwin Two-Cylinder Compound Engine Working Simple

that the total pressure on the large low-pressure piston shall not be greater than that on the high-pressure piston, and thus the low-pressure side kept from jerking the train and producing unequal strains on the two sides of the locomotive when working as a simple engine.

Operation of the intercepting and reduction valves.— In Figs. 25 and 26 the intercepting valve is marked *A* and the reducing valve *C*. It will be seen that they are both cylindrical in

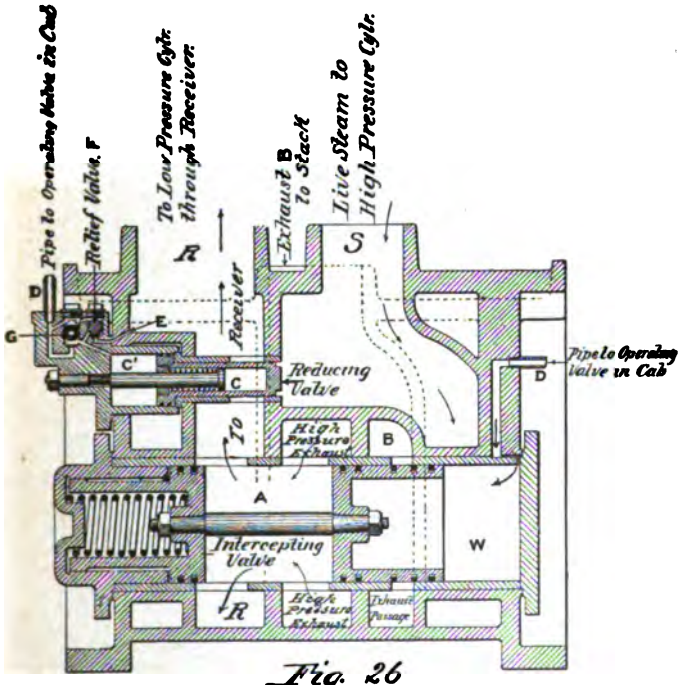


Fig. 26

Baldwin Two-Cylinder Compound Engine Working Compound.

form, are placed in bushings having suitable ports, and that coil springs hold them in their normal positions when no pressure is acting against them to overcome these springs.

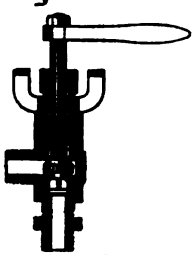
In the cab of the locomotive is placed an operating valve, shown in Figs. 27 and 28, having two positions, marked "SIMPLE" and "COMPOUND." Through this operating valve a pressure of air or live steam is admitted to one side of the reducing and the intercepting valves through two pipes marked *DD*, and, acting against the right end of valve *A* and against the left end of valve *C*, moves both from their normal positions shown in Fig. 25 to those of Fig. 26.

The reducing valve *C*, when it is not closed permanently by live steam from the operating pipe *D*, is automatically closed when the pressure in the receiver *R* is great enough to produce as much power in the large low-pressure cylinder as is obtained in the smaller high-pressure cylinder. For this purpose steam from the receiver *R* can pass through a port *E*, raising the poppet valve *F'* (which remains open as long as the engine is not working compound) and bears upon the larger end of the reducing valve *C*, causing it to move to the right and close the live steam passage *H* (shown in Fig. 25) leading to the receiver *R*, whenever the receiver pressure becomes excessive. Thus it will be seen that when the engine is working simple there must be a close balance between the left-hand larger end of the reducing valve, being acted upon by receiver pressure, and the right-hand smaller end of the reducing valve, being acted upon by live steam from the main steam pipe *S*. In this way is the receiver pressure kept as much lower than the boiler pressure as the large end of the reducing valve is greater than

the small end. This proportion is relative to the respective sizes of the high and the low-pressure cylinders and hence equal cylinder power will be given both sides of the engine in working simple. When the engine is standing, the lever of the small operating valve, Figs. 27 and 28, in the cab should be placed at position marked "SIMPLE," and the valves are then in position for the engine to work as a single-expansion locomotive, as the steam pressure is relieved through this cab valve from the large end of the reducing valve and the right-hand end of the intercepting valve, allowing these valves to assume (by the action of their springs) their respective positions shown in Fig. 25. The arrows in this figure illustrate clearly how the steam can pass from the high-pressure exhaust through the intercepting valve *A* to the independent exhaust *B* leading to the stack (see dotted lines and arrows). At the same time the passage of live steam to the receiver—from which the low-pressure cylinder receives its supply—takes place through ports *H*, as shown by other arrows. The receiver pressure is governed by the automatic action of the reducing valve, as previously explained.

Fig. 27.

Fig. 28.



Thus the engine can be used as a single-expansion locomotive in making up and starting trains,

and then, at the will of the engineer, the operating valve, Figs. 27 and 28, in the cab can be moved to the position marked "COMPOUND." This will admit live steam through the two supply pipes *D*, thence to the cylinders marked *W* and *C'*, Fig. 26, changing the intercepting and the reducing valves quickly, and, as the ports are small, noiselessly, to the position shown in the latter figure. With the intercepting valve in this position it will be seen that the independent exhaust *B* is closed and steam from the high-pressure exhaust must follow the course of the arrows to the receiver, passing around the small reducing valve bushing and its valve *C* which is kept closed by the live steam from pipe *D*.

At any time the engineer may desire to increase the power of the engine as, for instance, when in danger of stalling, by moving the lever of the operating valve in the cab to position marked "SIMPLE" the engine is again changed at once to a single-expansion locomotive.

Accidents to Baldwin Two-Cylinder Compounds.—With one side disabled, what should be done in order to safely run the engine in? Disconnect the disabled side, as advised for simple engines, place the intercepting valve in position for working simple so as to open the separate exhaust port, and run in with one side.

Should the small pipes *DD* leading to the reducing valve *C* and the intercepting valve piston be broken off, how could the engine be worked? With single-expansion only, unless the back head of the separate exhaust chamber *W* were removed

and the piston blocked in the position shown in Fig. 26; then the engine would become an automatic compound, that is, would start simple but automatically go to compound after a revolution or so.

What would it be advisable to do in case of a broken reducing valve? Use very light throttle at slow speeds, or run with a reduced boiler pressure.

Should the small valves *F* and *G* be frequently inspected and cleaned? Yes. These valves and the reducing and the intercepting valves become gummed by the injudicious use of cylinder oil on the low-pressure side.

THE SCHENECTADY COMPOUND.

Locomotives built by the Schenectady Locomotive Works are oftentimes styled by the older railway men as "McQueen" engines, although the name of the builders has been as at present for many years.

These builders have constructed many compound locomotives, and, including the original valve design, have employed three styles of compound mechanisms, but all engines built have been of the two-cylinder variety of compounds.

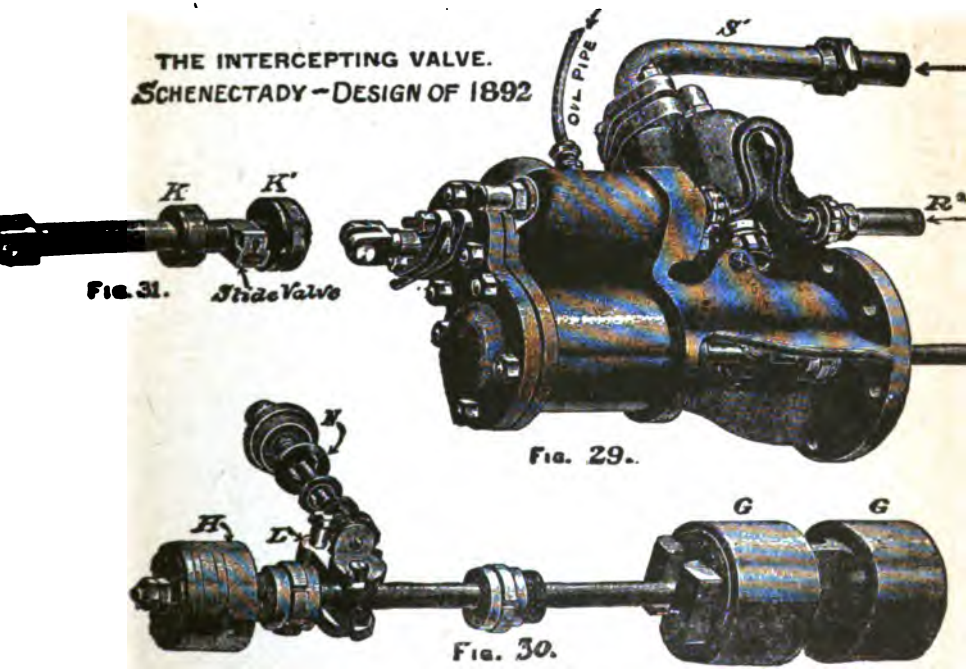
Original Schenectady Type.—The original design by their then superintendent, Mr. A. J. Pitkin, consisted of an intercepting valve and a reducing valve. The stem of the intercepting valve was connected by levers to an index in the cab, which showed its position to the engineer. These engines belonged to the class of automatic compounds.

In starting the engine, a small pipe from the boiler through a reducing valve supplied steam to the low-pressure cylinder at a reduced pressure. When the receiver had accumulated sufficient pressure by the exhaust into it from the high-pressure cylinder, the intercepting valve would automatically be thrown to its normal position for working compound; then the supply of live steam to the low-pressure cylinder was cut off and the receiver pressure admitted, and thus the engine worked compound.

The following modification of this valve arrangement was afterwards made by Mr. Pitkin and applied to many locomotives by the Schenectady Locomotive Works.

Design of 1892.—With this construction of 1892, the opening of the throttle admits live steam at the same time to both the high and the low-pressure cylinders, closes the intercepting valve and allows the engine to start with its full power as a simple engine. After a few strokes the receiver pressure automatically opens the intercepting valve and cuts off the passage of live steam to the low-pressure cylinder and the engine works compound. The special valves are located in and behind the saddle on the low-pressure side and are operated automatically and beyond the will of the engineer. Fig. 29 shows the general appearance of that portion of the intercepting valve projecting back of the saddle; Figs. 30 and 31 show the valves and pistons removed from their encasing chambers. Upon opening the throttle, a small connection from the

steam pipe admits live steam through suitable valves to an actuating piston, the movement of which opens a poppet valve, supplying live steam to the low-pressure cylinder, and also places the intercepting valve so as to close connection between the receiver and the low-pressure steam



chest. Thus the low-pressure cylinder exhausts to the atmosphere, and the high-pressure cylinder into a closed receiver. Sufficient pressure will accumulate in the receiver after a few strokes to move the small valves, thereby moving the actuating piston and with it the intercepting valve to

such position as will close off live steam to the low-pressure cylinder, and instead admit the receiver pressure, thus working the engine compound.

For the benefit of those interested in the details of this device, a more thorough description of the accompanying figures follows:

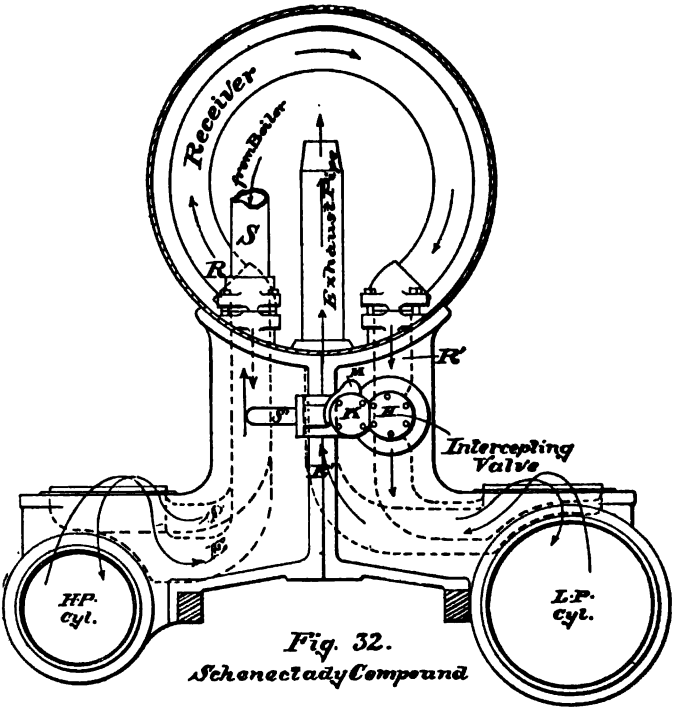


Fig. 32.
Schenectady Compound

The front view, Fig. 32, shows the general arrangement of cylinders, steam passages, and the intercepting valve. Figs. 33 and 34 both

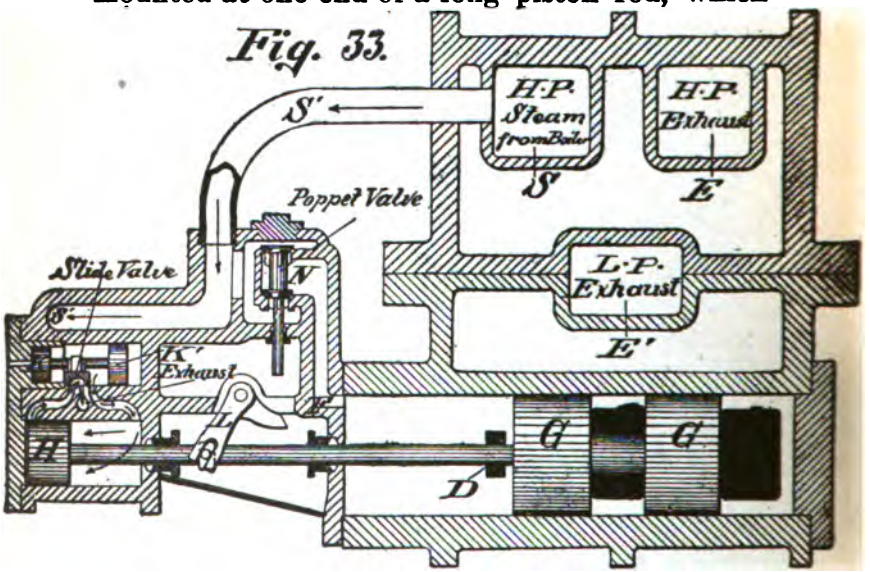
show the same horizontal section through the saddles and show the intercepting valve and the actuating valves, Fig. 33 showing them in position for working compound, and Fig. 34 for starting. Fig. 35 gives a vertical section, better showing the passages between the receiver and the low-pressure steam chest, which passages are opened and closed by the double pistons *GG* which form the intercepting valve. Of the remaining figures, 36 and 37 show details of the regulating valve, and Fig. 38 an end view of the intercepting pistons *GG*. The arrows in Figs. 33 and 34 indicate the direction of the steam in passing through the apparatus.

Fig. 32 shows a smoke-box mounted on saddles connected with the high and low-pressure cylinders located on opposite sides of the engine and having the necessary admission and exhaust ports. The exhaust port of the high-pressure cylinder is connected by a passage *E* (see dotted lines in Fig. 32 and full section of port in Figs. 33 and 34) with the receiver at *R*, Fig. 32. The other end of the receiver connects with the inlet passage R^1 (shown also in Fig. 35) leading to the low-pressure steam chest, and in this passage the intercepting valve *GG* is located and travels across it to open or close this passage.

The intercepting valve and the mechanism for operating it are mounted on the saddle of low-pressure cylinder, as before stated, while the live steam pipe *S* and the high-pressure exhaust passage *E* are situated in the high-pressure saddle. The low-pressure exhaust passage E^1 is formed

by the two saddles being bolted together, see Figs. 33 and 34.

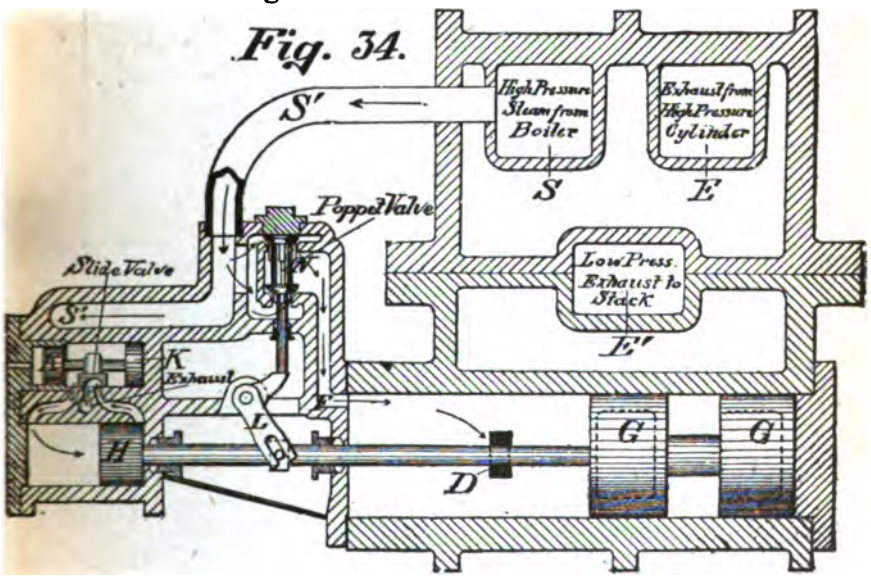
The intercepting valve consists of two pistons *GG* (having several small holes *g* through them in order to balance them, see Figs. 35 and 38) mounted at one end of a long piston rod, which



Intercepting Valve Open
Engine Working Compound

moves to and fro in a cylinder having four openings. The two large openings shown lead from the receiver to the low-pressure steam chest (see Fig. 35) and are closed by the two intercepting pistons *GG* when the engine is to be started, so that live steam may be admitted to the low-

pressure cylinder without producing a back pressure in the high-pressure cylinder through the receiver. Of the two remaining openings in the valve cylinder, port *D* leads to the low-pressure steam-chest and port *F* admits steam from the boiler when the apparatus stands in position as shown in Fig. 34.



Intercepting Valve Closed
Engine Working Simple

The back end of the intercepting piston-rod passes through suitable stuffing boxes to a small cylinder provided with a piston *H*, which actuates the intercepting valve. This cylinder has a small steam chest, slide valve and admission and exhaust

ports so similar to those of an ordinary locomotive cylinder, that its operation will be made plair by referring to the Figs. 33 and 34, if the movements of its slide valve are explained. This

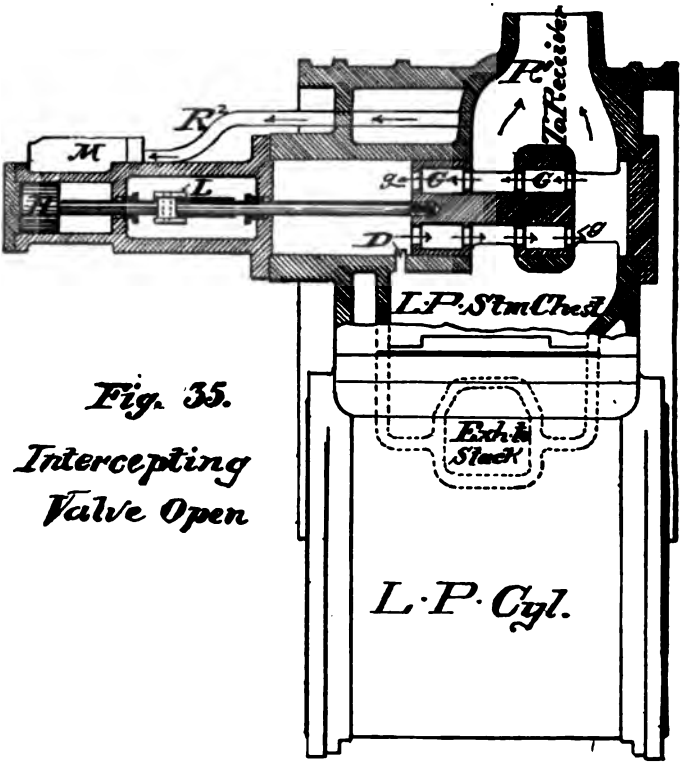


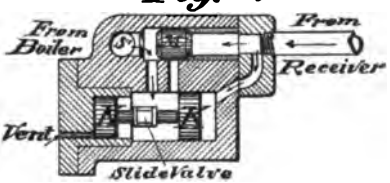
Fig. 35.
Intercepting Valve Open

small slide valve, Fig. 31, is moved by a stem connecting two pistons, K and K^1, of unequal diameter in order to insure their movement in the proper direction at the proper time. The actuation of these pistons, and with them the slide

valve, will be made clear by the figures. From Fig. 35 it will be seen that a small pipe R^2 leads from the receiver connection R^1 to this valve mechanism, and from Figs. 33 and 34, that a pipe S^1 comes from the live steam passage in the saddle and has a small port leading to the actuating valves as well as to the poppet valve N. These live steam and receiver connections come to opposite sides of a small piston valve M (Fig. 37), which is called the "regulating valve" and travels across two ports leading to the slide valve beneath it, as shown.

Fig. 36.

Fig. 37.

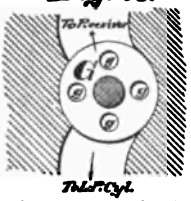


The remainder of this mechanism consists of a balanced poppet valve N, which, when open, admits live steam from pipe S^1 through the intercepting valve to the low-pressure cylinder in starting. This poppet valve N has a projecting stem on the lower side and is opened and allowed to close by a rocker-arm or bell-crank L, its two positions being shown in Figs. 33 and 34, respectively.

The operation of the apparatus is as follows: The normal position of the parts when the engine is working compound is shown in Fig. 33, in which position steam for the low-pressure

cylinder comes entirely from the high-pressure exhaust through the receiver. To start the train, the engine throttle is opened as usual. This permits steam to pass to the high-pressure side and also through the pipe S^1 (Figs. 33 and 36) to the left side of piston valve M (Fig. 37) and down through the adjacent port (as indicated by arrows) to the slide valve chamber, there acting between the two pistons K and K^1 (Figs. 31, 33 and 37). The right-hand piston, being the larger, causes a movement of the slide valve from its position shown in Fig. 33 to that shown in Fig. 34, thereby uncovering the steam port to the left of piston H, which it forces with the intercepting valve GG to the right. In this position,

Fig. 38.

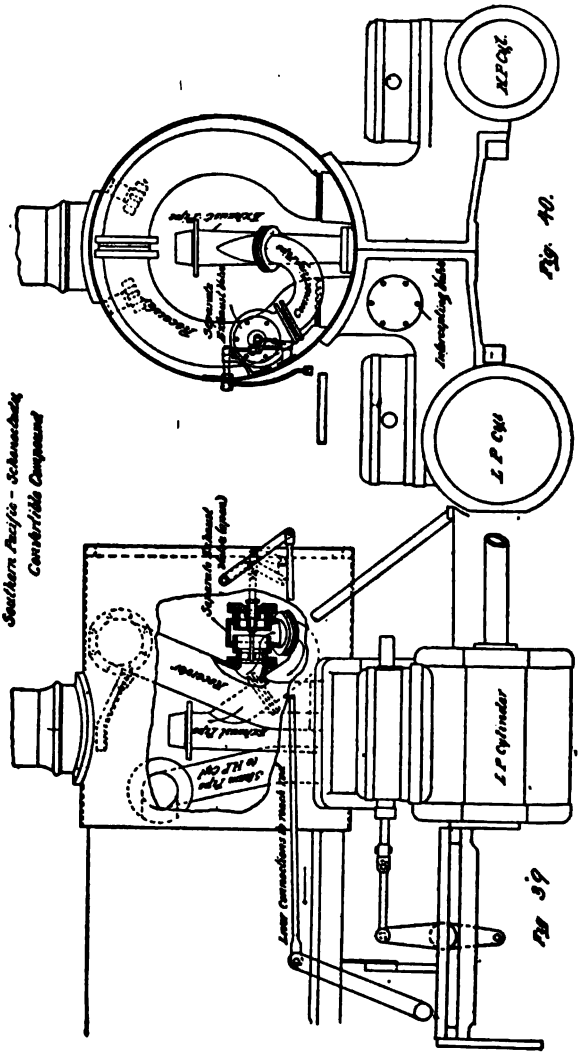


as shown in Fig. 34, the receiver openings are closed by the pistons GG and the poppet valve N has been opened by the bell-crank L, thus admitting live steam through the intercepting valve cylinder and port D to the low-pressure steam chest, as indicated by the arrows. Hence it is possible to obtain the full pressure of live steam in the low-pressure cylinder in starting.

After one or two revolutions the pressure in the receiver, passing down through the small connecting port to the right of the larger piston K^1 (Fig. 37) overbalances the pressures between the pistons, thus moving the slide valve to the left, the position shown in Figs. 33 and 37. According to the ordinary action of a slide valve this reverses the pressures on the actuating piston H, forcing it

to the left and opening the intercepting valve. This return movement of the actuating piston *H* detaches the bell-crank *L* from the poppet valve *N* and allows the latter to close before the intercepting valve opens. After this the locomotive works compound, the passage of steam being through the high-pressure cylinder to the receiver and thence through the intercepting valve and low-pressure cylinder to the atmosphere, as previously described.

A difficulty met with in many of the earlier forms of compound mechanism, and to which the reader's attention was called at the beginning of this chapter, namely, the accumulation of dangerously high pressure in the receiver when running with the throttle closed, was overcome in this device by an automatic action of the piston valve *M* and the differential pistons *K* and K^1 (Fig. 37), as follows: When the engine is using steam the regulating valve *M* is always against the right-hand seat, as shown, and this valve only comes into use when running without working steam, as down a long grade. In this case, if the intercepting valve happened to be closed, the action of the engine would cause air-pressure to accumulate in a closed receiver as there would then be no live steam available to cause the actuating device to open the intercepting valve. Hence it is arranged so that air-pressure in the receiver will force the valve *M* to the left and itself take the place of live steam by passing to the slide valve chamber and down to the right side of the actuating piston *H*, moving it to the


Southern Pacific - Schenectady
Consolidation Compound
L.P. Cyl.
L.P. Cylinder
Fig. 40.
Fig. 39

left and opening the intercepting valve, as shown in Fig. 33. Thus the small valve *M* acts as a safety valve, insuring the opening of the intercepting valve when live steam is not being used, and preventing the danger of excessive receiver pressure or the lifting of the high-pressure slide valve off its seat when the engine is running with steam shut off.

SCHENECTADY 1892 DESIGN, WITH SOUTHERN PACIFIC MODIFICATION.

To render it possible to run the engine "simple" for any desired period in starting, or to obtain a maximum power in case a train were stalling on a heavy grade, the Southern Pacific Co. in 1893 added to many of their Schenectady compounds of the 1892 design, a separate exhaust valve located in the smoke-box, as shown in Figs. 39 and 40. The reverse lever in the cab, when placed in either of its extreme positions, caused this valve to open and thereby connect the receiver directly with the main exhaust pipe, thus permitting the high-pressure cylinder to exhaust through the receiver directly to the atmosphere, as indicated by arrows in Fig. 39. As the receiver pressure was thus kept down it will be readily understood from the preceding description of the intercepting valve that the latter will remain in starting position as in Fig. 34, and hence the locomotive will work as a simple engine until such time as the engineer pulls the reverse lever higher up on the quadrant and thereby closes the separate exhaust valve. Then the

intercepting valve automatically assumes the compound position, as in Fig. 33, for reasons hereinbefore explained.

This modification of the two-cylinder or cross-compound is of especial note inasmuch as it was one of the first in this country which permitted the working of the locomotive as a simple engine for any desired length of time, at the will of the engineer. Its results in practical operation were to greatly reduce the jerking of trains in starting (then a very serious objection to many compounds); it gave a greater maximum power at critical periods, and was withal so eminently satisfactory that the reader will notice the majority of the builders of two-cylinder compounds in this country have embodied a separate exhaust valve in their later designs.

SCHENECTADY COMPOUND—DESIGN OF 1896. *

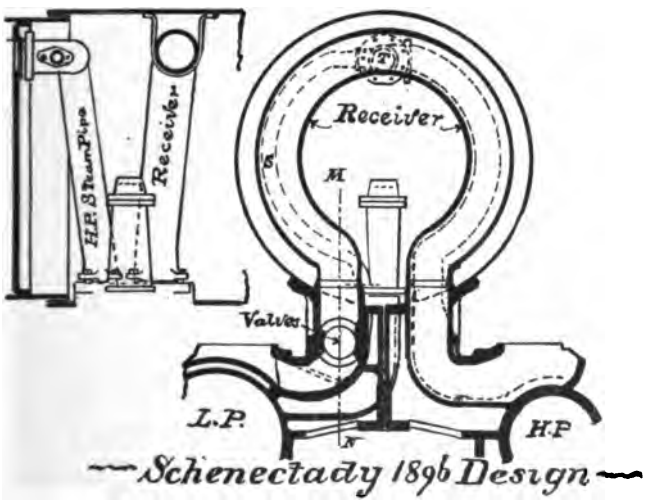
The valve arrangement designed in 1896 by Messrs. A. J. Pitkin, Vice-President and General Manager, and J. E. Sague, Mechanical Engineer of the Schenectady Locomotive Works, and used as their standard construction for two-cylinder compound locomotives, will be made clear by what follows.

In general it may be said that this so-called "intercepting valve" consists of four separate parts, namely: (1) An intercepting valve proper, which allows steam to pass to the low-pressure cylinder from either the receiver or the boiler, according to its position. (2) A reducing valve allowing live steam at only a reduced pressure

* This design is the "Schenectady" standard in 1906.

to enter the low-pressure cylinder when working simple. (3) An independent or separate exhaust valve which, when open, vents the exhaust from the high-pressure cylinder to the atmosphere through the exhaust pipe and stack. (4) A small valve *K* inside of the separate exhaust valve, by the use of which the latter can be opened more easily and gradually.

Fig. 41. *Fig. 42.*



By the arrangement of these valves the engine can be started and run either compound or simple and can be changed from compound to simple, or the reverse, at the will of the engineer, with the throttle and the reverse lever in any position; the engineer has only to move a small three-way cock in the cab and the working of the engine changes very smoothly and without jerking the train.

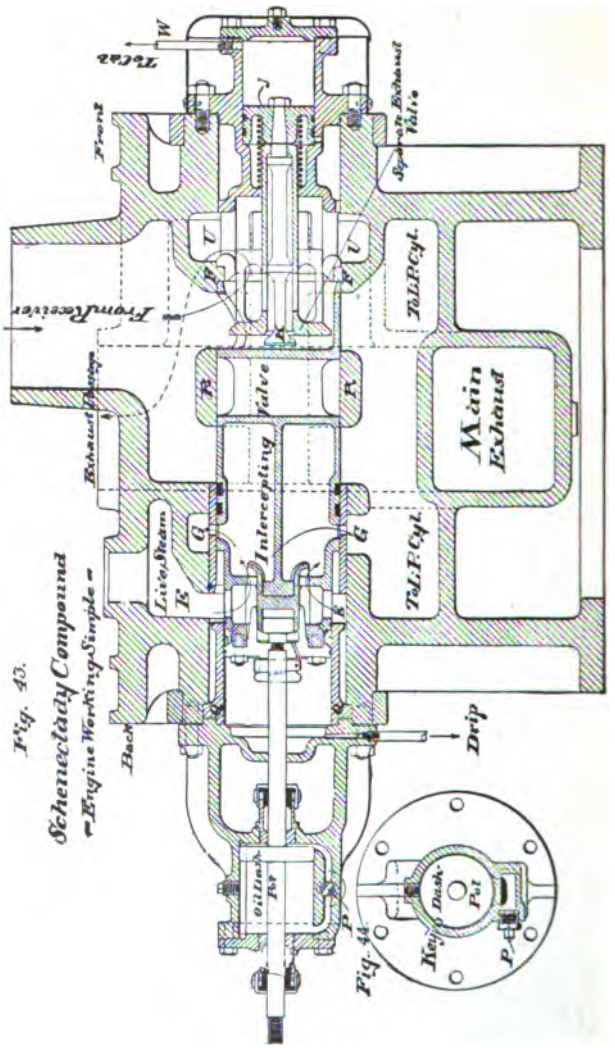


Fig. 43.
Schenectady Compound
Engine Working Simple
Front
Back
Tender
W
Separate Exhaust Valve
Front Receiver
Exhaust Passage
Live Steam
Intercepting Valve
H.P.
L.P.
H.P. Cyl.
L.P. Cyl.
Main Exhaust
Drip
Fig. 44
Key
Dash Pot
P

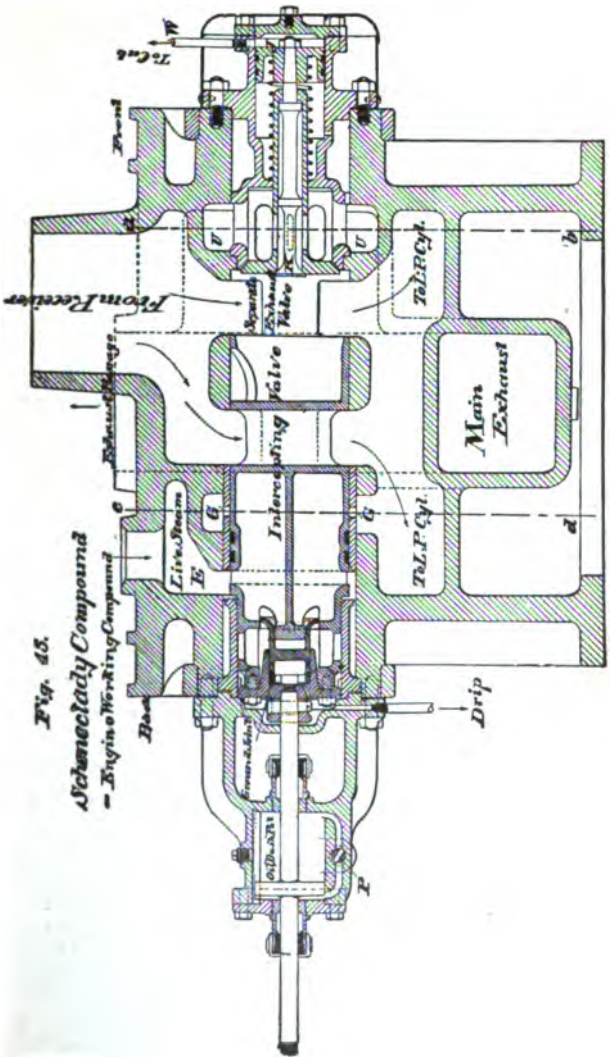


Fig. 45.

Schmeelcadly Compound
– Engine Working Compound

Figs. 41 and 42 give sections of smoke arch and cylinder saddles and show the steam passages, the receiver and the location of the intercepting valve in the saddle of the low-pressure cylinder on the right-hand side of the engine.

It will be noticed by the dotted lines behind the receiver pipe that there are two steam pipes as in a simple engine, but the one *(S)* leading to the intercepting valve on the low-pressure side is much smaller than usual, as it will only be required for use at low speeds.

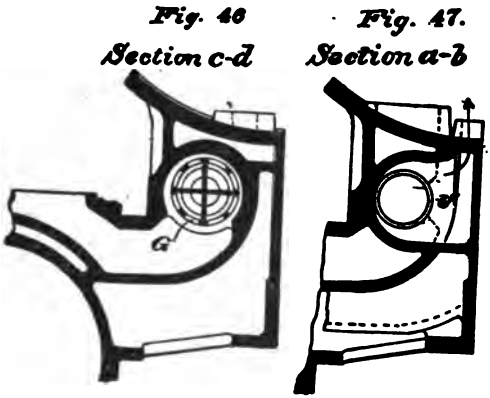
Fig. 43 shows a vertical section lengthwise through the low-pressure cylinder saddle and the intercepting valve (as if they were cut through at *MN* of Fig. 42) and shows the intercepting and the separate exhaust valves in the position taken when the engine is working simple and receiving live steam in both cylinders. Fig. 44 is a section through the dash-pot of Fig. 43.

Fig. 45 gives the same section as Fig. 43, but shows the intercepting and the separate exhaust valves in the position taken when the engine is working compound.

Figs. 46 and 47 show two sections crosswise of the intercepting valve at points indicated respectively by the lines *cd* and *ab* of Fig. 45. Section *cd* shows the passages *G* for admitting live steam into the low-pressure cylinder, and section *ab* shows the outlet passage *U* from the separate exhaust valve to the main exhaust pipe.

The part which each portion of the valve arrangement performs is as follows: The separate exhaust valve, when open, allows the steam

to exhaust from the high-pressure cylinder to the atmosphere without going through the low-pressure cylinder, thus working the engine simple; when it is closed, the high-pressure exhaust must pass through the low-pressure cylinder, thus working the engine com-



Intercepting Valve Passages.

pound. The intercepting valve closes the passage between the two cylinders when the separate exhaust valve is open, so that steam cannot go from the high-pressure cylinder to the low-pressure cylinder; thus doing away with back pressure on the high-pressure piston when the engine is working simple; it also admits live steam direct from the dry-pipe through the reducing valve to the low-pressure cylinder. When the separate exhaust valve closes, the intercepting valve automatically opens the pas-

sage between the two cylinders and cuts off the supply of live steam from the dry pipe to the low-pressure cylinder. The reducing valve works only when the engine is working simple and throttles the steam passing through it, so that the pressure of steam going to the low-pressure cylinder is about one-half (or, less, according to the proportionate sizes of the two cylinders) of that admitted from the boiler to the high-pressure cylinder.

The reducing valve is quite heavily cross-sectioned, while the long, intercepting valve appears next lighter, in order to render their outlines in Figs. 43 and 45 readily distinguishable. Examining the two ends of the intercepting valve, it will be seen that the left end, exposed to the pressure of the atmosphere through the drip, is only about three-fourths as large as the right end (between the bridges *R R*, Fig. 43), exposed to the receiver; hence, if the receiver has little or no pressure, the boiler pressure on the shoulder of the intercepting valve automatically carries it to the right, as shown in Fig. 43. The reducing valve is automatically opened because of the difference in area of its two ends also. The movement of each of these valves is cushioned by dash-pots, as shown. The separate exhaust valve is operated by the engineer by means of a three-way cock in the cab. To open the separate exhaust valve the handle of the three-way cock is thrown so as to admit a pressure of steam or air through the pipe *W* against the piston *J*. Pulling the handle back relieves the pressure

against piston *J* and the spring shuts the valve, as in Fig. 45. All the engineer has to do in connection with the operation of the valves is to pull the handle of the three-way cock in the cab one way or the other, according as he wishes the engine to run simple or compound. The engineer uses the handle under the following conditions:

To Start Simple.—Under ordinary conditions this is not necessary, but if the maximum power of the engine is needed to start a heavy train, the engineer pulls the handle of the three-way cock so as to admit pressure from the cab through pipe *W* against the piston *J*, Fig. 45. This will force piston *J* into the position shown in Fig. 43, opening the separate exhaust valve and holding it open. The engine throttle now being opened, live steam at boiler pressure enters the chamber *E* from the small steam pipe *S* before mentioned and forces the intercepting valve to the right against the seat *FF*, as shown in Fig. 43. The exhaust steam from the high-pressure cylinder now passes through the receiver and is exhausted through the separate exhaust valve to an annular chamber *U* connected with the main exhaust to the stack, as indicated by the arrow in Fig. 43. (See also Fig. 47.) Steam also enters the low-pressure cylinder from chamber *E* through the reducing valve and the annular ports *G* in the intercepting valve (See Figs. 43 and 46), and is exhausted in the usual way. The reducing valve prevents the full boiler pressure from reaching the low-pressure cylinder. As will be seen from

Figs. 43 and 45, the reducing valve is partly balanced by its smaller left end being open to the atmosphere through a small groove leading to the chamber having an open drip, and thus the boiler pressure acting on the unbalanced area throws the valve open—to the right. When the pressure in the intercepting valve cavity on the right of the reducing valve becomes high enough, it will throw the valve to the left, because it acts on the whole area of the valve; the result is that the steam is throttled to the proper pressure desired for the low-pressure cylinder.

To Work Compound.—Having started the train, when the engineer wishes to change the engine from simple working to compound, he pushes the handle of the three-way cock to its first position which, relieving the pressure on piston *J* through pipe *W*, allows the spring to act to the right and close the separate exhaust valve, as in Fig. 45. As soon as this valve is closed the pressure in the receiver, having no outlet, rises and presses the intercepting valve to the left against the pressure from chamber *E*, which acts only, as stated, upon the shoulder of the intercepting valve. The receiver pressure holds the intercepting valve to the left, as shown in Fig. 45, thereby closing the ports *G* and opening a free passage from the receiver to the low-pressure cylinder as indicated by the arrows, and the engine works compound. While working compound, which is the usual way of working the engine, both the reducing and the intercepting valves are held to the left against ground joint seats. This should prevent any

steam which might leak by the packing rings from constantly escaping at the drip.

To Change from Compound to Simple.—With the engine running compound, if the engineer wishes to change to simple because of a very heavy grade, he has only to pull the three-way cock handle to the same position as for starting simple. Then piston *J* first opens the small valve *K* and then the separate exhaust valve. The small valve *K* relieves the pressure more gradually than if the larger valve were opened at once. As soon as the separate exhaust valve is opened the pressure in the receiver escapes through it and becomes so low that the intercepting valve is again forced to the right (as in Fig. 43) against its seat *F* by the steam pressure from chamber *E*, and the engine works simple as in starting.

To Start as an Automatic Compound.—If the separate exhaust valve is left closed, as in Fig. 45, the engine will start as an automatic compound when the throttle is opened, for the pressure from chamber *E* will force the intercepting valve to the right, as in Fig. 43, thus admitting live steam through the reducing valve and ports *G* to the low-pressure cylinder, while at the same time the high-pressure cylinder exhausts into a closed receiver for a few strokes. This pressure, accumulating in the receiver, will then automatically close the ports *G* by moving the intercepting valve to the left, as in Fig. 45, and the engine thereafter runs compound.

Accidents to Schenectady Compounds—the Automatic Compound of 1892. What should be done

in case of a break-down on the road; necessitating the disconnecting of the high-pressure side? If but a short distance to go and a slow speed would suffice, clamp the high-pressure slide valve in center and permit the engine to run by the admission of live steam through the small pipe S^1 and the poppet valve N to the high-pressure cylinder (Figs. 33 and 34). If the intercepting valve is out of order, block the poppet valve N open, that is, up. If it were required to run at considerable speed, this small pipe S^1 would give insufficient supply, in which case the high-pressure slide valve should be blocked clear back (much farther than its ordinary travel carries it), so as to uncover the exhaust port, thus admitting live steam direct to the receiver. If the steam chest is large enough to place the high-pressure valve as described, and the intercepting valve is not deranged, the engine would run at full speed with the low-pressure side. If out of order, the intercepting valve should be held open (in the position as shown in Fig. 33) by clamping the stem between the stuffing boxes. In all cases the throttle should be handled easily to prevent a too rapid flow of boiler pressure to the large low-pressure cylinder and the consequent liability of jerking the train or causing damage to this cylinder.

What should be done if it becomes necessary to take down the low-pressure side of the engine? The engine could be moved a short distance with the cylinder cocks open or the indicator plugs removed on the high-pressure side, but as most en-

gines of this class have either a large steam chest or an "Allen" ported slide valve, the valve can be clamped back far enough to uncover the low-pressure exhaust port, and thus run at full speed. If this cannot be done, block both the low-pressure crosshead and valve clear back and unscrew the relief valves or take off the front cylinder head on that side to make an exhaust opening from the receiver. If the intercepting valve is out of order, it must be securely clamped open, as in Fig. 33, otherwise the opening between the receiver and the low-pressure steam chest would be closed.

In this last procedure, with the exhaust other than through the stack, would the engine steam with much of a train? No; but a limited amount of steam could be maintained by the use of the blower for creating draught.

What would be the effect of the removal of the slide valve on the disabled side? This would give a free port opening under all circumstances, but would generally consume too much time to be practicable.

What prevents the leakage of live steam into the receiver when the intercepting valve is closed, as in Fig. 34, there being no packing rings in the two pistons *GG*? The live steam pressure acts from below when starting, so as to hold these pistons tight against ports of the receiver. Fig. 35 illustrates this clearly, if the intercepting

valve were there shown closed, as live steam would then be below pistons *GG*.

What would be the result if the wiper *L* would strike the poppet valve *N* (Figs. 33 and 34) before the intercepting valve pistons *GG* closed their ports? Live steam would blow through to the receiver and produce a back pressure on the high-pressure side.

How can this be prevented? Pistons *GG* have sufficient lap to allow of their closing before the wiper *L* strikes the poppet valve *N*, and the adjustable tappet on the intercepting valve stem should be set so as to cause this. If the tappet is set too far back, valve *N* would not be opened at all and, as a consequence, no live steam would be admitted to the low-pressure cylinder in starting.

If the operating piston *H* should break, what position would the intercepting valve probably take? On account of the unbalanced area of the stem, it would probably move open to the left as for compound working, Fig. 33.

Accidents to Schenectady design of 1892, *with Southern Pacific Modifications.*—If it became necessary to disconnect the high-pressure side of the engine, what should be done? The same as with the 1892 Schenectady system.

Would there be any difference in case the low-pressure side broke down? Yes; disconnect the broken side as usual (see instructions for simple engines in Part First of the Manual) and run with reverse lever in full gear, if for a short distance or a low speed only is required. If it is necessary to run for a considerable distance at a good speed it

would be advisable to disconnect the separate exhaust valve levers from their connection to the reach-rod and properly secure them in either extreme position, so as to hold the valve open. The engine can then be "hooked-up," that is, the reverse lever pulled up toward its central position, to correspond to the demands of the service.

Accidents to Schenectady Compounds—design of 1896.—What should be done in case the high-pressure side had to be disconnected? Ordinarily, open the separate exhaust valve * and do nothing different than with a simple engine; but to obtain greater speed than the supply of live steam to the low-pressure cylinder through its small steam pipe would permit, the high-pressure valve should be secured in such a position, if possible, as will uncover its exhaust port, thereby admitting live steam to the receiver and thence to the low-pressure cylinder. In this case leave the separate exhaust valve closed and handle the throttle easily so as not to cause constant opening of the safety valves on the low-pressure side.

What is necessary with the low-pressure side disconnected? Open the separate exhaust valve and allow the high-pressure cylinder to exhaust to the stack through its connection. While considerable train could thus be handled, it would not be done at anything but a slow speed, unless the low-pressure slide valve were placed so as to

* While not absolutely necessary to open the separate exhaust valve for this case, it is best to do so that there may be no accumulation of pressure in the receiver should the high-pressure valve leak.

uncover its exhaust port and the separate exhaust valve left closed.

What is done to prevent full boiler pressure from reaching the low-pressure cylinder in case the reducing valve becomes defective or broken? Pop or safety valves are placed on the chest and both heads of the low-pressure cylinder and they are set at about one hundred pounds, the highest pressure deemed advisable in so large a cylinder.

In case of a broken intercepting valve what precautions should be taken? Run the engine compound only and do not stop the engine with the low-pressure side on center.

Why must the oil dash-pot be kept filled with oil? The flow of oil from one side of the dash-pot piston to the other prevents sudden movements of and serious jars to the intercepting valve.

How can the rapidity of this movement be regulated? By a greater or less opening of the valve *P*, Figs. 43 and 44, as this valve regulates the flow of oil from one side of the dash-pot piston to the other. A slight opening causes a slow movement, while a wide opening makes possible a too rapid movement.

What would be most liable to cause breakage to the intercepting valve? Allowing the oil dash-pot to become partially or wholly empty.

What kind of oil should be used in this dash-pot? Only mineral oil, thinner, if anything, than ordinary engine oil.

What is the purpose of the key shown in the dash-pot (Fig. 44)? To prevent the intercepting valve from turning around.

With this compound, what pressure from the cab is used to operate the separate exhaust valve? Either air or steam.

Why is air pressure generally considered preferable? On account of the absence of moisture therein. As the separate exhaust valve piston *J* and its cylinder (Figs. 43 and 45) project from the front of the cylinder saddle and are exposed to currents of cold air, the use of steam therein and a lack of proper drainage might cause them to freeze in cold weather.

What objection is there to the use of air? Should the air pump stop or the pressure otherwise become exhausted, as in switching and picking up a large number of air-brake cars, there might be insufficient pressure to hold the valve open against the receiver pressure.

How is this objection overcome when air is used for this purpose? Besides the air connection to the three-way cock in the cab, there is a steam connection; closing the one and opening the other, quickly furnishes an alternative pressure for operation.

What would be the result if both the steam and the air connections were left open? There would be no effect upon the engine itself, but the steam would fill the whole air-brake system with water and seriously affect the operation of the brakes.

Mallet Articulated Compound Locomotive (American Locomotive Company).—The Mallet articulated compound locomotive is one having two sets of cylinders, compounded together and driving independent groups of wheels. The two sets of cylinders are supplied with steam from a single boiler; which makes it practically two locomotives combined in one, and having only one boiler. The rear group of wheels is carried in frames rigidly attached to the boiler in the usual manner, while the frames which carry the front group of wheels are not secured to the boiler, but support it by means of sliding bearings. There is a hinged connection between the frames of the front engine and those of the rear engine, about which the former is permitted a limited swing in relation to the latter. It will be seen that the front group is a truck which swivels radially about its articulated connection with the rear group, when the locomotive passes through a curve. It is from this feature that the articulated type of locomotive derives its name.

Because of the fact that only the rear group of wheels is carried in rigid frames, the articulated type of locomotive provides a short rigid wheel base capable of passing through curves of short radius. At the same time, the total number of wheels is greater than in the ordinary types of locomotives; and the weight is distributed over a

greater number of axles. Consequently, an enormous weight with corresponding tractive power may be provided in this type without an excessive weight per wheel on the rail. In an articulated compound locomotive having twice as many driving wheels as a given locomotive of the rigid-frame type, double the tractive power of the latter is available, with the same weight per driving wheel on the rail and with no increase in the length of the rigid wheel base. Or vice versa, with the same tractive power in each case, the weight per driving wheel on the rail of the articulated compound locomotive may, by the use of the proper wheel arrangement, be reduced to one-half of that of a given locomotive of any of the types in ordinary use.

The work being divided between two sets of pistons, crank pins, rods, and driving axles, an enormous tractive power is obtained in the articulated compound locomotive with practically no increase in the weights of the moving parts over those of a locomotive of the rigid-frame type, having half the tractive power; or with the same tractive power in each case the moving parts of the articulated locomotive may be made much lighter than those of locomotives of other types.

In addition to the advantages due to its wheel arrangement, the articulated compound locomotive possesses all those resulting from compounding the steam. This type of compound locomotive is what is known as a two-stage compound; that is, the steam is used successively in two sets of cylinders. Steam from the boiler is admitted to

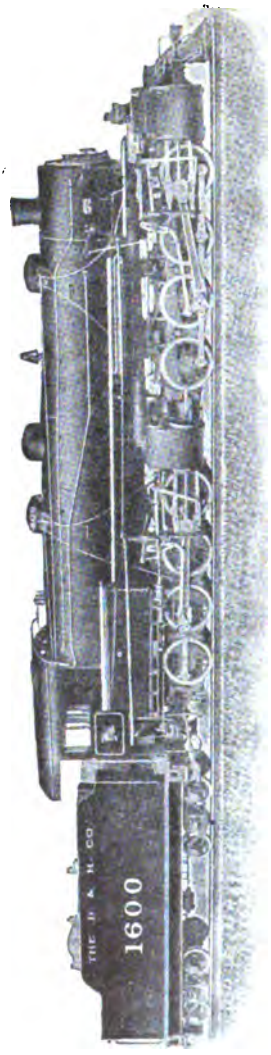


FIG. 1. MALLET ARTICULATED COMPOUND LOCOMOTIVE.

the first set or high-pressure cylinders, which ordinarily drive the rear group of wheels; and, having done work in those cylinders, is then used over again in the second set or low-pressure cylinders which are connected to the front group of wheels. From the low-pressure cylinders, the steam is exhausted to the atmosphere.

Between the high and low pressure cylinders and connecting the two is a large pipe called the receiver, into which the steam from the high-pressure cylinders exhausts when the locomotive is working compound. The receiver is simply a reservoir in which the exhaust steam from the high-pressure cylinders is stored until it is required by the low-pressure cylinders. From the receiver, the steam is admitted into the low-pressure cylinders by their valves in the usual manner.

The low-pressure cylinders have a larger piston area than the high-pressure cylinders, the ratios between the two being such that, at the ordinary working cut-off, the steam at the lower pressure per square inch acting against the larger piston area, exerts the same force as the higher pressure steam acting on the smaller area. Consequently, the high and low pressure cylinders having the same stroke, each set of cylinders ordinarily does practically the same amount of work.

By using the steam successively in two sets of cylinders, a greater range of expansion is obtained than in a simple or single expansion locomotive. In other words, the difference between the pressure of the steam entering the high-pressure cylinders and the pressure it has when the exhaust

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By using the steam successively in two sets of cylinders, a greater range of expansion is obtained than in a simple or single expansion locomotive. In other words, the difference between the pressure of the steam entering the high-pressure cylinders and the pressure it has when the exhaust

from the low-pressure cylinders opens, is greater than in the case of the simple locomotive.

In a simple locomotive, the steam is ordinarily expanded only four times, while in a two-stage compound six or seven expansions are obtained. As a result, more work is performed by the same amount of steam in a compound than in a simple locomotive; and a considerable saving in coal and water consumption is thereby effected.

Moreover, compounding divides the range of temperature between the two sets of cylinders; so that the condensation in the cylinders is reduced, which effects a further saving in fuel and water consumption.

In every compound locomotive some provision must be made for admitting steam direct from the boiler to the low-pressure cylinders in starting and until the exhaust from the high-pressure cylinders supplies the low-pressure cylinders with steam. Also, provision is usually made by which in case of emergency when additional hauling capacity is required, the locomotive may be changed from working compound into simple with an increase in power. In this articulated compound locomotive, these functions are performed by a special mechanism called the intercepting valve, which is located between the receiver and the exhaust passages from the high-pressure cylinders.

Another device used by some locomotive builders, in place of the intercepting valve, is an arrangement by which, on opening a valve operated from the cab, communication is established between the two ends of the high-pressure cylinder

through a by-pass pipe; and live steam reduced in pressure by passing through this pipe is admitted to the receiver and so to the low-pressure cylinders.

With the by-pass arrangement, when the locomotive is working simple, live steam is necessarily admitted to both sides of the high-pressure pistons. Consequently, these pistons are very nearly balanced. At the same time, the live steam which is admitted to the low-pressure cylinders is reduced in pressure. The result is that under these conditions, when the locomotive is starting or working simple, practically all of the work is done by the low-pressure cylinders, and little, if any, increase in power is secured.

In the American Locomotive Company's system of compounding, the intercepting valve is so designed that when the engine is working simple the exhaust from the high-pressure cylinder passes directly to the atmosphere and the valve cuts off communication between the receiver and the exhaust side of the high-pressure pistons, thus relieving them of back pressure, except that of the steam exhausting to the atmosphere. Moreover, the live steam from the boiler reduced to a pressure of somewhat above the ordinary pressure in the receiver is admitted to the low-pressure cylinder. Hence, the low-pressure pistons are exerting more power than when working compound. This additional power, added to that secured in the high-pressure cylinders, because of the reduction of the back pressure, gives a total increase in power when working simple of

about 20 per cent. The intercepting valve also automatically regulates the pressure of the live steam entering the receiver when starting and when working simple, keeping it at such a pressure that each of the four cylinders does practically the same amount of work.

INTERCEPTING VALVE.

Among the distinctive features of this articulated compound locomotive, practically, the only ones which enter into its operation are the intercepting valve, the power reversing gear, and the by-pass valves.

The intercepting valve is identical in principle with that used on the two-cylinder cross-compound locomotives known as the Richmond Compound, differing from the latter only in certain modifications of the design which the use of four cylinders instead of two necessitates. Engineers, therefore, who have operated the two-cylinder cross-compound of this build, will be perfectly familiar with the construction and operation of the intercepting valve as applied to this locomotive.

This valve is located in the saddle of the left high-pressure cylinder, to the left of the vertical and above the horizontal center line of the cylinders. It consists, in reality, of three valves, viz., the intercepting valve, the reducing valve or sleeve, and the emergency or high-pressure valve.

The various parts comprising the whole mechanism are shown in detail in Fig. 2.

Parts 2, 3 and 5 constitute the intercepting valve proper.

This valve shuts off, at the proper time, communication between the receiver and the high-pressure cylinders, to prevent the pressure in the receiver backing up against the high-pressure

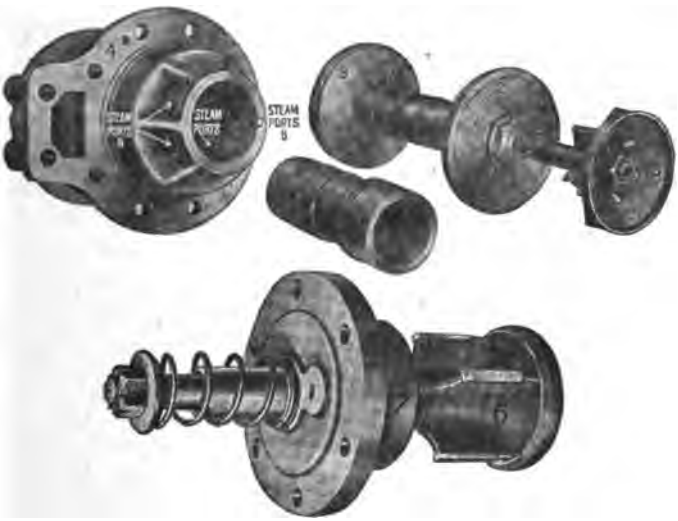


FIG. 2. PARTS OF THE INTERCEPTING VALVE.

No. 1. Reducing Valve or Sleeve.
No. 2. Intercepting Valve.
No. 3. Dash-pot Piston.
No. 4. Intercepting Valve Chamber Head.
No. 5. Unbalancing Valve.
No. 6. Emergency or High-pressure Exhaust Valve.
No. 7. Emergency Valve Chamber Head.

pistons, when the locomotive is working with live steam in all four cylinders.

The reducing valve or sleeve, 1, fits on the stem of the intercepting valve, 2, along which it is free to slide longitudinally. Its duty is three-fold:

First, to close the intercepting valve in start-

ing and when the locomotive is changed from compound to simple working;

Second, to let live steam from the boiler into the receiver and low-pressure steam chests in starting and when the locomotive is working simple;

Third, to regulate the supply of this live steam and keep its pressure at a predetermined amount.

The emergency or high-pressure exhaust valve, 6, which is located at one of the outer ends of the intercepting valve chamber, is the device which makes it possible to change the locomotive from compound to simple working (that is, using live steam in all four cylinders).

A wrought iron pipe leads from the emergency valve chamber along the left side of the locomotive to an elbow at the rear of the main exhaust pipe. This elbow connects with a passage surrounding the main exhaust opening.

When the locomotive is changed into simple working, the emergency valve, 6, is opened, which allows the exhaust steam from the high-pressure cylinders to pass through the wrought iron pipe to the exhaust pipe in the smoke box and to the atmosphere.

Opening of the emergency valve is accomplished by opening the emergency operating valve, which is indicated by the letter N in Fig. 3. When the emergency operating valve is closed (when the locomotive is working compound), the handle of the valve points *forward.*

To open the emergency operating valve, N, and

change the locomotive into simple, the handle must be turned so as to point *backward.* The opening and closing of the emergency valve, 6, is thus under the control of the engineer.

It is important to bear in mind that the emergency valve, as its name indicates, should ordinarily be used only when the locomotive cannot otherwise move the train; and, as soon as a speed of three to four miles per hour has been attained, the locomotive should be changed back to compound.

Except for changing the locomotive into simple, the movements of all the parts of the intercepting valves are automatic.

The illustrations in Figs. 4, 5, 6 and 7 show the entire mechanism assembled, and the arrangement of the various steam pipes and passages. These illustrations also give the intercepting valve in its four different positions; namely:

Fig. 4, the moment after the throttle is open when starting in the ordinary way, the reducing valve, 1, being open and the intercepting valve, 2, and the emergency valve, 6, closed;

Fig. 5, at the time when the predetermined pressure has been reached in the receiver pipe, when the reducing valve, 1, is closed and the other parts remain in the same position as in Fig. 4;

Fig. 6, in the compound position, when the intercepting valve, 2, is open and the reducing valve, 1, and the emergency valve, 6, are closed;

Fig. 7, in simple position, when the emergency or high-pressure exhaust valve, 6, and

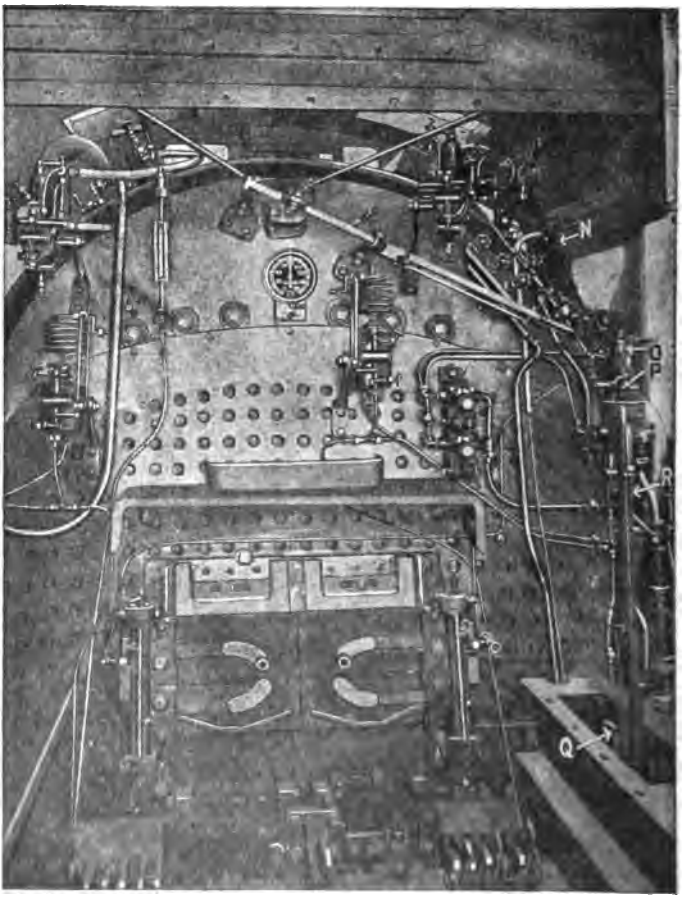


FIG. 3. INTERIOR VIEW OF THE CAB OF A MALLET ARTICULATED COMPOUND LOCOMOTIVE.

N. Emergency Operating Valve.
O. Engineers' Straight Air Brake Valve.
P. Engineers' Automatic Brake Valve.
Q. Main Reverse Lever.
R. Auxiliary Reverse Lever.

the reducing valve, 1, are open, and the intercepting valve, 2, is closed.

In these illustrations, the course of the steam is indicated by arrows, and helps to make clear the explanation of the principle and operation of this system of compounding.

As will be seen from Fig. 7, the reducing valve, 1, is so fitted on the stem of the intercepting valve, 2, that when the former opens, it closes the latter, and vice versa. The reducing valve, however, can be closed without opening the intercepting valve.

OPERATION OF THE INTERCEPTING VALVE.

Referring to Fig. 4, live steam from the boiler is, as indicated by the arrows, always admitted through the cored passages in the cylinder casting to the chamber, A, formed in the intercepting valve chamber head, 4, and surrounding the reducing valve, 1. Chamber C communicates with the receiver pipe or steam passage to the low-pressure cylinders, and chamber F connects directly with the exhaust passages from the high-pressure cylinders. The chamber L communicates with chamber M through the emergency or high-pressure exhaust valve, 6. The latter chamber is connected with the exhaust pipe in the smoke box, as previously explained.

With the intercepting valve in the position shown in Fig. 4, steam from the boiler, following the course of the arrows, flows through the passage in the left high-pressure cylinder to cham-

ber A, and acting against the shoulder, E, of the reducing valve, 1, has forced this valve open or inward, closing the intercepting valve, 2, and uncovering the ports, B. This allows live steam to pass into the chamber C, and thence into the receiver and to the low-pressure steam chests and cylinders. Live steam, at the same time, passes through the high-pressure valve into the high-pressure cylinders in the ordinary way. The intercepting valve, 2, being closed, communication between the exhaust passage, F, from the high-pressure cylinders and the chamber, C, is cut off. This thus prevents the pressure in this latter chamber from backing up against the exhaust side of the high-pressure pistons; and, consequently, these start free from back pressure; while, at the same time, the low-pressure cylinders are being supplied with steam direct from the boiler. The pressure of this steam is so regulated by the reducing valve, 1, that it bears the same relation to the boiler pressure as the high-pressure piston areas bear to the low-pressure piston areas, thus making the work in all four cylinders equal (the high and low pressure cylinders having the same length of stroke). For instance, if the area of the low-pressure cylinder is two and one-half times the area of the high-pressure cylinder, then the reducing valve, 1, would be so designed as to reduce the pressure of the live steam admitted by it to chamber C, to $1 \div 2.5$ or 40 per cent. of the boiler pressure.

From the above, it will be seen that the locomotive automatically starts with live steam in all

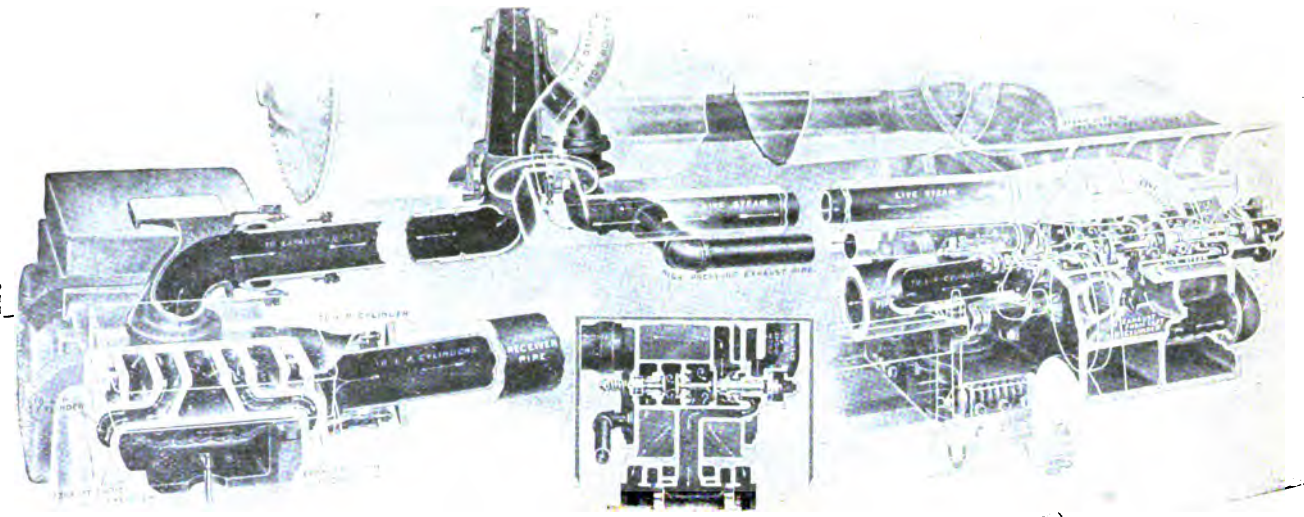


FIG. 4. POSITION OF THE INTERCEPTING VALVE THE MOMENT AFTER THE THROTTLE IS OPEN WHEN THE LOCOMOTIVE IS STARTED IN ORDINARY WAY.

Reducing Valve 1 is open, Intercepting Valve 2, and Emergency Valve 6, are closed. Live steam is admitted to all four cylinders and the high pressure pistons start free from back pressure.

four cylinders, or, in other words, as a single expansion engine.

Piston, 3, and the chamber, H, in the outer end of the intercepting valve chamber head, 4, constitute simply an air dash-pot, to prevent slamming of the valves when changing from compound to simple when running.

Fig. 5 represents the intercepting valve at the moment when the predetermined maximum pressure in the low-pressure steam chests is reached. In this case, it will be noticed that the positions of the valves are the same as in Fig. 4, except that the reducing valve, 1, has been moved out, closing the ports, B, thus cutting off the supply of live steam to the chamber C, and to the low-pressure steam chests; until by the movement of the low-pressure pistons the pressure in that chamber has been lowered to the required amount.

The reducing valve automatically keeps the pressure in the chamber C down to the desired amount because of the fact that the area of the shoulder E is, as previously stated, usually $1 \div 2.5$ or 40 per cent. of the area of the end D of the valve. Consequently, when the pressure in the chamber C exceeds 40 per cent. of the boiler pressure, it will overcome the force of the steam at boiler pressure, acting on the shoulder E; and move the reducing valve, 1, outward, closing ports B.

The intercepting valve automatically assumes the compound position, Fig. 6, after one or two revolutions of the driving wheels. In this position, the intercepting valve 2 is opened, allowing

the exhaust steam from the high-pressure cylinders to pass into the chamber C, and so to the receiver and the low-pressure cylinders. The

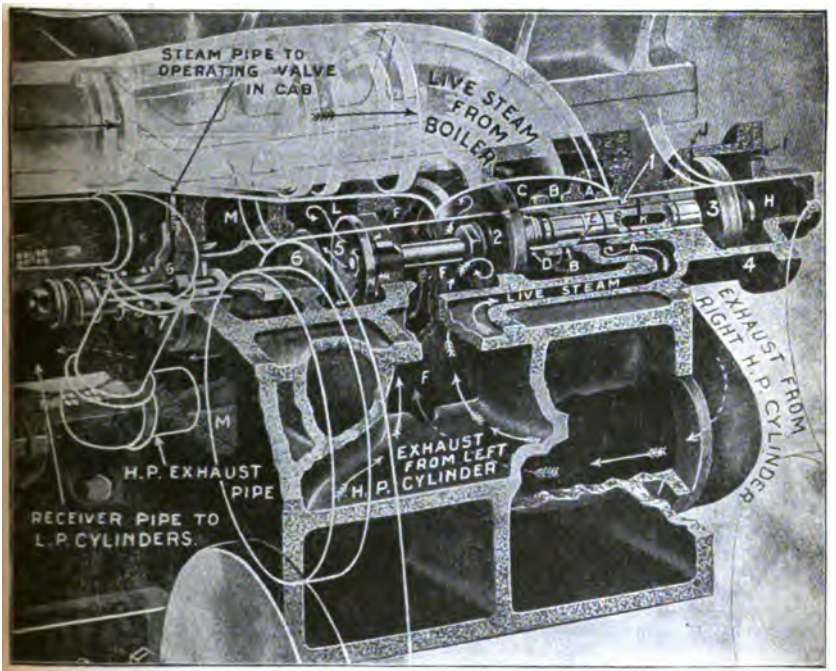

STEAM PIPE TO OPERATING VALVE IN CAB
LIVE STEAM FROM BOILER
LIVE STEAM
EXHAUST FROM RIGHT H.P. CYLINDER
EXHAUST FROM LEFT H.P. CYLINDER
H.P. EXHAUST PIPE
RECEIVER PIPE TO L.P. CYLINDERS.

FIG. 5. POSITION OF THE INTERCEPTING VALVE WHEN THE PREDETERMINED PRESSURE IN THE RECEIVER PIPE HAS BEEN REACHED.

Reducing Valve or Sleeve 1 is closed: the other parts remain the same as in Fig. 4. Live steam is cut off from the receiver until the pressure is reduced to the proper amount.

opening of the intercepting valve 2 has closed the reducing valve, 1, which thus cuts off the supply of live steam to the chamber C and receiver.

The principle by which these movements are automatically performed may need some explanation. The exhaust steam from the high-pressure cylinders in the chamber F acting against the inner face of the intercepting valve, 2, and also against the inner end of the intercepting valve stem (being admitted to the chamber L through the holes in the unbalancing valve, 5), tends to open the intercepting valve 2. This force is resisted by the pressure on the outer face of the intercepting valve 2, the pressure on the outer and inner faces of the unbalancing valve, 5, being balanced. The combined areas of the face of the intercepting valve 2 and the end of its stem are greater than the area of the outer face of the valve. Thus steam in the chamber F at a lower pressure acting against this larger area overcomes the resistance of the higher pressure steam in chamber C and forces the valve into the position shown. This principle is the same as in the case of the reducing valve previously explained.

These areas are usually so proportioned that when the pressure in the chamber F is 30 per cent. of the boiler pressure, it overcomes the resistance of the steam in the chamber C at a pressure of 40 per cent. of boiler pressure.

As will be seen from the above, when the locomotive is working compound the low-pressure steam chests receive all of their steam from the exhaust from the high-pressure cylinders through chambers F and C and the receiver, the ports B having been closed by the outward movement of the intercepting valve 2. At full stroke, the pressure

on the low-pressure pistons would be, approximately, 30 per cent. of the boiler pressure; while, on the high-pressure pistons, would be exerted the

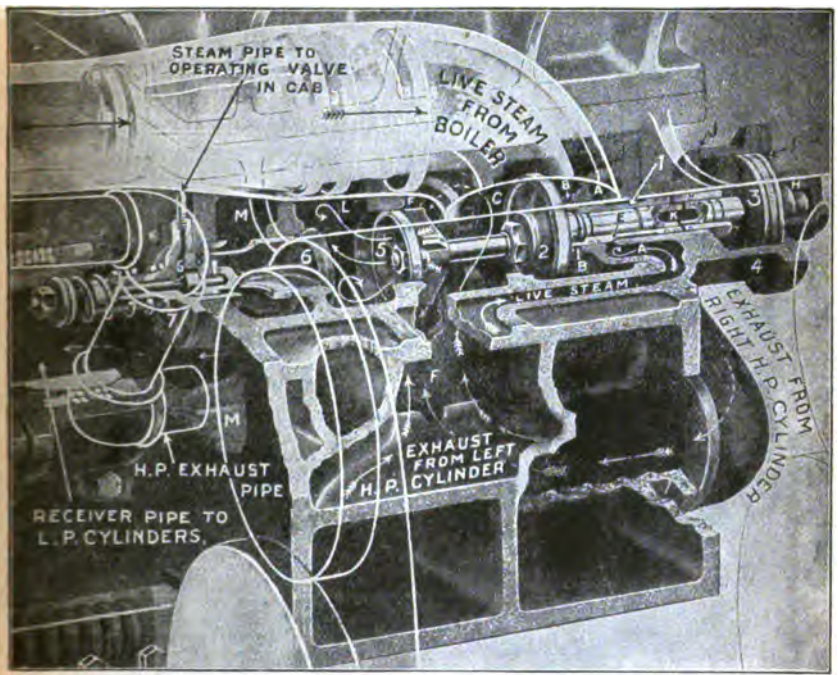

STEAM PIPE TO OPERATING VALVE IN CAB
LIVE STEAM FROM BOILER
LIVE STEAM
EXHAUST FROM RIGHT H.P. CYLINDER
EXHAUST FROM LEFT H.P. CYLINDER
H.P. EXHAUST PIPE
RECEIVER PIPE TO L.P. CYLINDERS.

FIG. 6. INTERCEPTING VALVE IN COMPOUND POSITION.

Intercepting Valve 2 is open. Reducing Valve 1 and Emergency Valve 6 are closed. Live steam is cut off from the receiver pipe and exhaust steam from the high pressure cylinders is admitted.

pressure which the live steam from the boiler has, minus the 30 per cent. in the receiver which acts on their exhaust sides. The pull on the cross

heads of all four cylinders is practically equal, as the products of the several piston areas multiplied by their respective pressures are equal in each case.

Should the maximum power of the locomotive be required in starting or in ascending a heavy grade, it may be had at any time by simply turning the emergency operating valve N in the cab so that the handle points to the *rear*. The intercepting valve will then assume the position shown in Fig. 7.

Opening the emergency operating valve admits live steam into the chamber G, which forces the emergency valve, 6, open against the resistance of its own spring plus the pressure of the steam in the chamber L (which is receiver pressure).

On the opening of the emergency exhaust valve, 6, the steam in the chamber L is immediately released. This unbalances the intercepting valve, 2, with the result that the reducing valve, 1, is moved inward or opened by the pressure of the steam from the boiler in chamber A acting against the shoulder E. The reducing valve, 1, carries the intercepting valve 2 inward with it, closing the latter, the two valves assuming the position shown in Fig. 7. Communication between the chamber C and the chamber F, into which the steam from the high-pressure cylinders exhausts, is thus cut off; while live steam from the boiler, at a pressure reduced to about 40 per cent. of the boiler pressure, is allowed to pass through the ports B into the chamber C and thence through the receiver to the low-pressure steam chests.

By the use of the intermediate chamber L between the chamber F and the emergency valve, 6, which is exhausted the instant that valve is

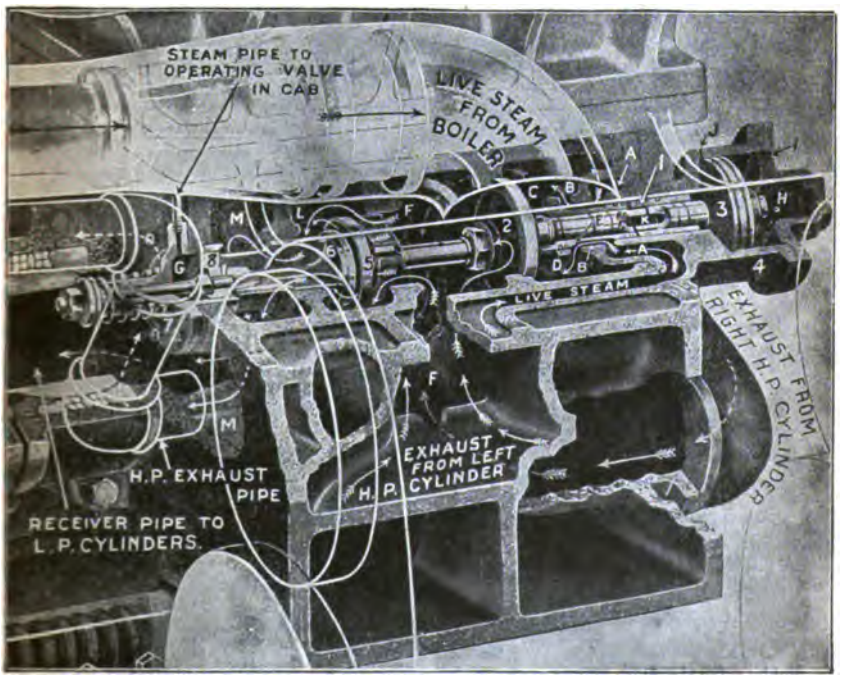

STEAM PIPE TO OPERATING VALVE IN CAB
LIVE STEAM FROM BOILER
LIVE STEAM
EXHAUST FROM RIGHT H.P. CYLINDER
EXHAUST FROM LEFT H.P. CYLINDER
H.P. EXHAUST PIPE
RECEIVER PIPE TO L.P. CYLINDERS.

FIG. 7. INTERCEPTING VALVES IN SIMPLE POSITION.
Emergency Valve 6 and Reducing Valve 1 are open and Interceptive Valve 2 is closed.
The exhaust from the high-pressure cylinders is released to the atmosphere, the high-pressure cylinders are relieved of receiver pressure and live steam is admitted to all cylinders, giving 20 per cent. increase in tractive power.

opened, the intercepting valve 2 is closed and the reducing valve 1 opened before, or at the same moment, that the receiver is actually exhausted.

Consequently, there is no drop of pressure in the low-pressure steam chests during the change from compound to simple or prior to the entrance of live steam into the low-pressure steam chests.

As the emergency exhaust valve, 6, is kept open by the pressure of the steam admitted to the outer side of the piston 8 by the opening of the emergency operating valve in the cab, the exhaust steam from the high-pressure cylinders passes through the chamber F into the chambers L and M, and so into the high-pressure exhaust pipe and to the atmosphere.

Thus when the intercepting valve is in position shown in Fig. 7, that is, when the locomotive is working simple, the high-pressure pistons are relieved of the back pressure amounting to 30 per cent. of the boiler pressure, which acts against them when the locomotive is working compound, with the intercepting valve in Fig. 6. On the other hand, the low-pressure cylinders are receiving steam direct from the boiler at a pressure of 40 per cent. of that which it has in the boiler, instead of exhaust steam from the high-pressure cylinders at a pressure of only 30 per cent. of boiler pressure, as when the locomotive is working compound. This explains the 20 per cent. increase in the normal maximum power, which, as already stated, is obtained by changing the locomotive into simple. The increase would be greater were it not for the wire-drawing of the steam through the restricted area of the ports B, which are intentionally reduced for operation under this con-

dition. As it is, the actual increase in power at speeds of from three to four miles per hour would not be greater than the amount given above.

The reducing valve, 1, is so designed that at speeds of more than three or four miles an hour no increase in power is obtained by changing the locomotive into simple. This is done in order that the emergency feature will not be misused, with injurious effect on the machinery and the sacrifice of economy in fuel consumption.

If the pressure in the chamber C and consequently in the receiver pipe and the low-pressure steam chests rises to more than 40 per cent. of the boiler pressure when the engine is working simple, the reducing valve, 1, will be forced outward to the position it has in Fig. 5; that is, closing the ports B and shutting off the live steam from the chamber C. The other parts of the valve, however, will remain in the same position as shown in Fig. 7. The reducing valve 1 automatically closes under the conditions above stated.

Upon the movement of the low-pressure pistons, the steam pressure in the chamber C will be reduced; and the boiler pressure acting upon the small shoulder E would again force the reducing valve 1 inward to its position in Fig. 7, opening the ports B. Thus the pressure in the chamber C and low-pressure steam chests would be again raised to the required 40 per cent. of the boiler pressure. This alternate opening and closing of the reducing valve 1 will continue as long as the displacement of the low-pressure pistons does not exceed the supply of steam that

comes through the ports B. When this condition occurs, the reducing valve 1 will remain open.

These facts explain why, if the locomotive starts to slip when it is changed into simple, it automatically ceases without necessitating closing the throttle; since, with the rapid movement of the low-pressure pistons, the power of those engines is reduced; and, with the increased exhaust from the high-pressure engines passing through the comparatively restricted opening of the emergency valve 6, the back pressure on the high-pressure pistons is increased, reducing the effective power in those cylinders.

It is very important for the engineer to remember that, the locomotive having been changed into simple working by opening the emergency operating valve N in the cab, it is necessary to close this valve (that is, turn it so that the handle points *forward*), in order to change the locomotive back to compound or normal working. With the emergency operating valve closed, the steam will be exhausted from the chamber G in front of the piston 8. The tension of the spring, assisted by the steam pressure upon the inner end of the emergency exhaust valve 6, will then return that valve to its seat, thus preventing the exhaust steam from the high-pressure cylinders escaping to the stack. A few exhausts from the high-pressure cylinders will, then, soon raise the pressure in the chamber F and force the intercepting valve 2, and with it the reducing valve 1, to assume the compound position, as shown in Fig. 6.

If, upon starting the locomotive, it is desired to

prevent the valves from changing automatically to the compound position, the emergency valve 6 may be opened in advance by opening the emergency operating valve N, turning the handle to the *rear*. This, as previously explained, will prevent the pressure in the chamber F from rising sufficiently to force the intercepting valve 2 open.

In changing from compound to simple when running, the sudden unbalancing of the intercepting valve 2, tends to close this valve rapidly, with the result that it would slam, were it not for the dash-pot, which prevents this. The dash-pot piston 3 at the outer end of the intercepting valve stem works in the cylinder H formed in the outer end of the intercepting valve chamber head 4. When the intercepting valve is forced inward under full pressure, its too rapid motion is prevented by the slow escape of the air from under the piston 3 through the small port J. This is practically the only function of the dash-pot. The port K, extending through the center of the intercepting valve stem half way to the inner end, permits the escape of any steam that may leak past the small rings on the intercepting valve stem and reducing valve 1.

All of the ports of the intercepting valve have important duties to perform, and their location and sizes must not be changed.

From the above description of the intercepting valve, it will be seen that to start a train with an articulated compound it is usually only necessary to open the throttle in the ordinary way with the reverse lever in the position required for

the weight of the train or, ordinarily, in the extreme notch; and with the cylinder cocks open. The intercepting valve will automatically assume the position shown in Fig. 4, and the locomotive will work simple until the pressure in the receiver has raised sufficiently to force the intercepting valve 2 into position shown in Fig. 6, or compound position.

If the locomotive fails to move the train when started in this way, or is about to stall on a steep grade, it should be changed into simple working by turning the handle of the emergency operating valve in the cab, so that it points to the *rear*, which causes the intercepting valve to assume position shown in Fig. 7.

There is no increased tendency for the locomotive to slip when working simple; and, moreover, when it does slip, the slipping is automatically arrested after only a few inches of movement of the piston. If, however, the locomotive starts to slip, it is advisable to use sand, should the rail conditons be at all unfavorable.

The engineer can easily tell whether the locomotive is working simple or compound either by the sound of the exhaust or by the position of the emergency operating valve in the cab. When working simple there are eight exhausts to each revolution of the wheels, and only four when working compound. In the former case the exhaust has more the sound of a continuous blow, the separate exhausts being less distinct. When working compound, the handle of the emergency

operating valve, as stated, points *forward,* and to the *rear* when working simple.

If the low-pressure engine fails to start when the throttle is open, the trouble may lie in the reducing valve 1 having stuck in the closed position, due to the fact that it had not been properly lubricated or some foreign matter had worked into the bore of the valve. In such an event the admission ports B, Fig. 4, would be closed and no steam could get to the low-pressure cylinder.

Such a difficulty can ordinarily be remedied by giving the reducing valve a little more feed of oil for a few minutes; or, if necessary, the cover of the dash-pot H may be removed and with a piece of bent ¼-inch wire the reducing valve 1 may be moved in and out a few times, after which it will probably clear itself when the throttle is open.

The intercepting valve should be given a liberal feed of oil for a minute before starting and occasionally during long runs when the throttle is not shut off for a considerable length of time. Outside of this, one drop of oil every four or five minutes is ordinarily ample when running.

POWER REVERSING GEAR.

Because of the size and weight of the parts of the valve motion of this articulated compound locomotive, a power reversing gear is generally applied to operate the reverse lever. This is an engine consisting of two cylinders, one an air cylinder and the other filled with oil. The two

cylinders are set one ahead of the other, and are usually bolted to the underside of the mudring or some other convenient location.

Fig. 8 shows the arrangement and construction of this mechanism. In this case the forward one is the air cylinder and the rear the oil cylinder, although this arrangement is usually reversed and can be made whichever the circumstances require. In any arrangement both pistons are mounted on a common piston rod which is connected to either the main reverse lever, or, as in the illustration, to an extension of the reverse shaft arm.

Between the two cylinders are the packing boxes for the common piston rod, and there is also a stuffing box at the air end of the cylinder for the rod connecting the piston with the reverse lever or shaft, as the case may be. Both pistons are packed with leather packing, that in the air cylinder being held out by spring rings. The valves of both cylinders are conical, that for the air cylinders having four openings in addition to the exhaust cavity, while the oil cylinder valve has two crossed passages.

The valves of the air and oil cylinders are operated by an auxiliary reverse lever R to which they are connected by a rod. This lever is pivoted on the main lever Q at the point W. It is provided with a latch with teeth that fit in a quadrant in the same manner as the main lever. This latch is so interlocked with the latch of the main reverse lever Q that raising the former raises the latter, which cannot drop again unless the main

reverse lever Q is in its normal position relative to the auxiliary lever R.

The levers are so designed that when the two latches are lifted the auxiliary reverse lever R is allowed sufficient movement about its pivot point W (limited by lugs on the main reverse lever latch) to give a full opening of the valves of the air and oil cylinders.

When a change in cut-off is desired the latch of the auxiliary lever R is released, which also unlatches the main reverse lever Q. If the main reverse lever Q is to be thrown ahead, the auxiliary lever is moved forward about its pivot point W, and back, if it is desired to move the main lever in that direction. The movement of the auxiliary lever R, forward or back, swings its lower end Y which operates the valves of the air and oil cylinders; and the valve motion is moved in the desired direction.

For instance, when the auxiliary lever is pushed forward, its lower end Y is drawn back. This turns the valve of the air cylinder so that the air is admitted through the air inlet 13 to the front of the piston, and the exhaust port 14 establishes communication between the rear end of the air cylinder and the exhaust to the atmosphere. At the same time the crossed passages of the oil cylinder valve are so turned as to allow the oil in the cylinder to flow from one end to the other. The air and oil pistons thus move back and the valve gear is moved forward. The slow flow of the oil in the oil cylinder prevents the too rapid movement of the reverse lever Q.

The auxiliary lever R, being pivoted on the main reverse lever Q, moves with the latter, and when the gear is to be changed must be kept in motion until the desired notch in the quadrant is reached and then latched. By stopping the movement of the auxiliary lever, the gear automatically moves the main reverse lever up to its normal position relative to the former, when it also latches, as already stated. This also automatically closes the valves of both the air and oil cylinders, giving both an oil and a positive lock to the gear.

Except in case of lack of air pressure or any accident to the power reversing gear, the valve motion is handled entirely by the auxiliary reverse lever R. For this reason the practice is to cut off that portion of the main reverse lever Q which ordinarily projects above the deck of the cab, thus leaving more room for the engineer. A separate handle is provided for the main reverse lever, which may be easily applied in case of accident to the power reversing gear.

It is, of course, important that the air and oil valves be properly set so that the valve openings and cylinder ports match up properly in the different positions. For example, a quarter of a turn of the oil valve one way or the other would result in the valve being blanked instead of open when the auxiliary lever R was moved about its pivot point. The gear could not, then, be operated, as the oil could not circulate from one end of the oil cylinder to the other. If, therefore, the power reversing gear fails to operate when

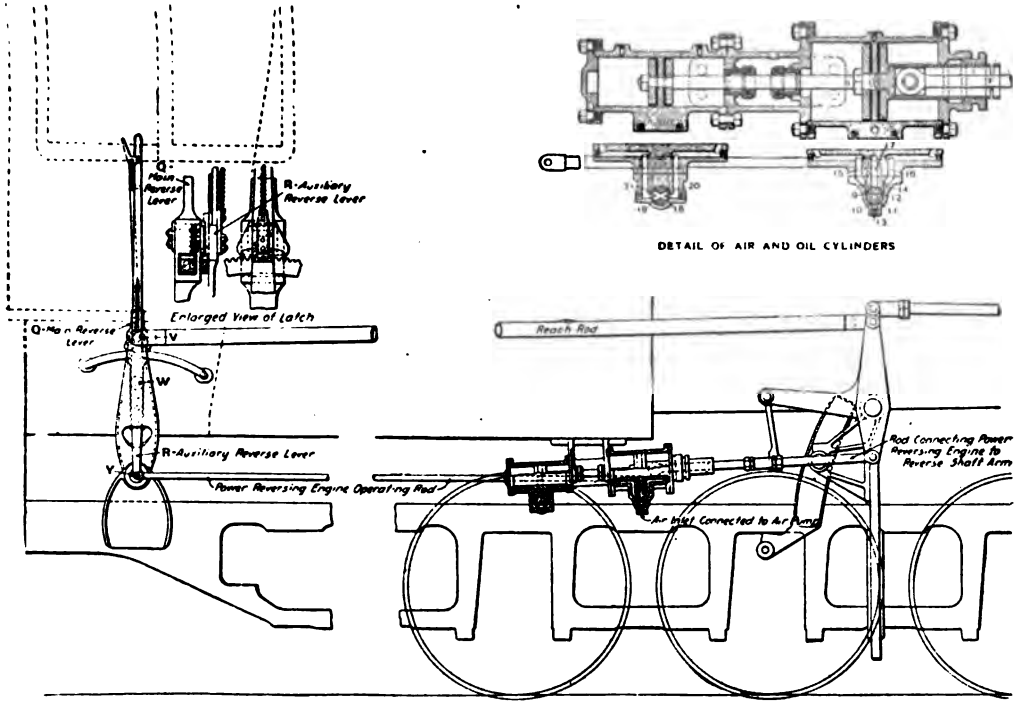


FIG. 8. POWER REVERSING GEAR.

the valves are supposedly opened and nothing has happened to the air supply, first examine the valves to see that they are in their proper position.

The function of the oil cylinder is to prevent the too rapid movement of the reversing gear when a change of cut-off is made. It is imperative, therefore, that this cylinder be always kept full of oil. The frequency with which it should be filled depends on the condition of its piston and piston rod packing and these should, therefore, be kept in good condition. If the reversing gear operates too rapidly, this indicates that there is a lack of oil in the oil cylinder and this should be refilled and the leakages stopped.

In case of any repairs to the power reversing gear, especial attention should be given to see that it is properly adjusted when set up so that when the gear is operated the main reverse lever will automatically be moved to its normal position relative to the auxiliary lever and properly latch. If the gear is not properly adjusted, the latch of the main reverse lever will not engage properly with the teeth of the quadrant. In consequence the latch of the auxiliary lever will have to hold the gear with the result that it will be quickly worn.

BY-PASS VALVES.

Another feature which plays a most important part in the successful operation of the articulated compound locomotive, and so should be

clearly understood by the engineer, is the by-pass valves.

The purpose of these valves is to prevent the injurious effects which would otherwise result from the pumping action of the large low pressure pistons when the locomotive is drifting.

These valves are so designed that they automatically establish communication between the two ends of the cylinder, when the engine is running with the throttle closed, thus performing several important functions.

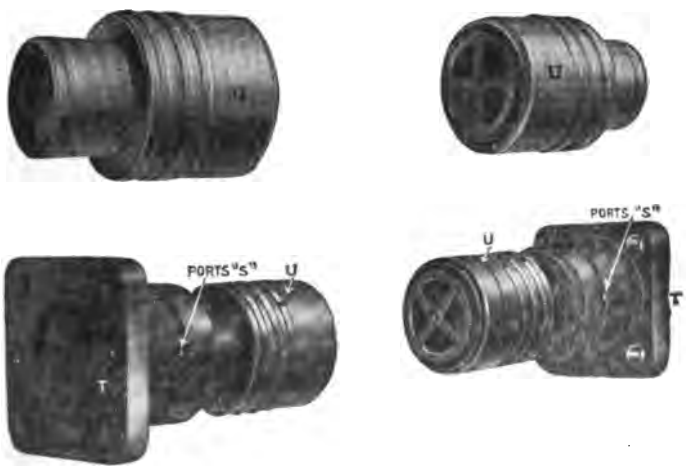


FIG. 9. BY-PASS VALVES

First, they prevent alternating vacuum and compression in the cylinders when the locomotive is drifting, thus insuring the free movement of the pistons.

Second, by permitting the circulation of the

free air drawn into the cylinders through the vacuum-relief valves, they prevent this air from being overheated by the churning of the pistons and thus destroying the lubrication, when the locomotive is drifting down a long hill.

Third, by destroying the vacuum which, without them, would be formed by the large piston, they prevent the smoke and gases from the smoke box being sucked into the cylinder.

Fourth, they prevent excessive fanning of the fire from the pumping action of the large pistons when drifting

These valves are located in chambers cast in the outside of each low pressure cylinder. Their construction is shown in Fig. 9. There are two valves to each cylinder. The lower view in the illustration shows the two valves U with the heads T of the chambers in which they are located; while the upper view shows the valves alone without the valve chamber heads.

Fig. 10 illustrates the arrangement or the valves when assembled in their chamber and their relation to the steam ports in the cylinders.

In position A of this latter figure, the valves U are in the position they assume when the throttle is open. In this position the steam passing from the steam chest ports through the small ports S in the head T of the valve chamber, as indicated by the arrows, acts against the outer ends of the valves U and keeps them against their seats, cutting off communication between the admission ports of the cylinders.

Position B of Fig. 10 is the one the by-pass

valves U automatically takes when the throttle is closed. In that event the atmospheric pressure admitted through the small air vent in the valve chamber forces the valves U open, closing the steam chest ports and establishing communication between the admission ports at either end of the cylinders. This permits circulation from one end of the cylinder to the other when the locomo-

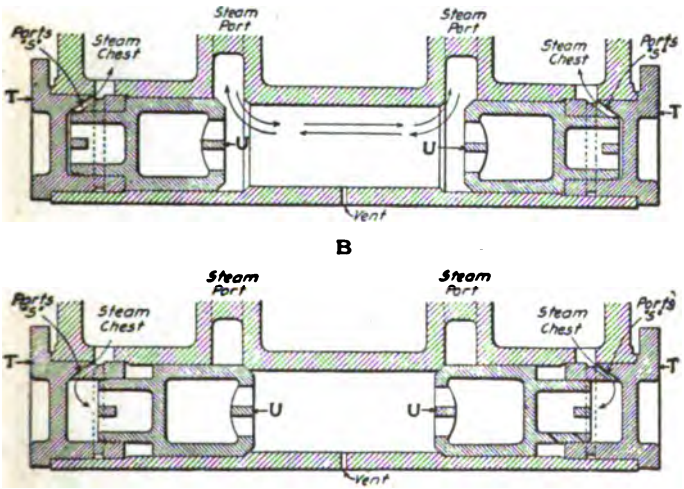


FIG. 10. BY-PASS VALVES IN OPEN AND CLOSED POSITION.

tive is drifting, accomplishing the necessary results enumerated.

It is strongly recommended, therefore, that in drifting the reverse lever be kept at ¾-stroke or

more, since when operated in this way the locomotive will drift freely.

As the by-pass valves perform such important duties, it is essential that they be properly cared for and kept in good condition, to prevent them from sticking. The engineer can tell at once if the by-pass valves are stuck open, as, in that case, steam will blow from the small pipe projecting from under the jacket midway between the ends of the cylinder. This pipe connects to the air vent in the center of the chamber containing the valves.

From the above description it will be seen that if the by-pass valves stick open it will cause a severe blow. When the locomotive is first put into service the by-pass valves should be taken out and cleaned quite frequently to keep them free of core sand which will undoubtedly work in. After this has been done a few times they require only ordinary attention.

If the low pressure engines are heard to thump as if a piston, crosshead or box were loose and the locomotive does not drift freely, the trouble probably lies in the by-pass valves being stuck closed by being gummed, and these should be taken out and cleaned at the first opportunity.

Sticking of the by-pass valves may be caused by smoke box gases being sucked into the cylinders by the pistons when the locomotive is drifting with the reverse lever "hooked up." These gases would be sent circulating through the by-pass valves which are oily from the steam, and the soot may stick to them and form a gum. This

gum hardens gradually and the valves ultimately work so hard that the comparatively light suction in the steam chest is not strong enough to open them. On this account periodical cleaning of these valves should be made.

The possibility of smoke and gases being sucked into the cylinders will be minimized, if the reverse lever is kept at ¾-stroke or more when the locomotive is drifting.

VACUUM AND RELIEF VALVES.

In the high pressure steam chests or some other convenient place which is in communication with the steam chests, are located vacuum valves. The function of these valves is to admit free air into the steam chests when the locomotive is drifting so as to avoid a vacuum and give a moderate flow of air through the cylinders.

The low pressure cylinders are equipped with combined vacuum and relief valves which in addition to having functions similar to the vacuum valves of the high pressure cylinders also regulate the steam pressure in the low pressure steam chests. These relief valves are set at 45 per cent of the boiler pressure.

As these valves relieve any excessive pressure in the low pressure cylinders, they should be tested occasionally to see that they are correctly set.

From the previous description of the intercepting valve it will be seen that when the locomotive is working compound the packing rings of the high pressure valves and pistons alone separate

the boiler pressure from the pressure in the receiver and low pressure cylinders. Consequently if there was a blow in these packing rings, the pressure in the receiver would be increased, causing the relief valves in the low pressure steam chests to blow off. Therefore, if these valves rise from their seats frequently when the locomotive is working compound, it might be due to the fact that there was a blow in either the valves or the pistons of the high pressure cylinders, and these should be tested.

To test for blows simply throw the emergency operating valve in the cab to the simple position, namely, with the handle pointing to the *rear*. Spot the locomotive and test the same as a simple locomotive.

FLEXIBLE JOINTS.

Another feature peculiar to the articulated compound locomotive is the flexible ball and slip joint steam pipe connections.

In this articulated compound locomotive there is a ball joint connection between the receiver pipe and the high pressure cylinders, a slip joint connection between the receiver pipe and the Y-pipe by which the steam is carried to the steam passages of the low pressure cylinders, a ball joint connection between the exhaust pipe flexible connection and the low pressure cylinders and also between the former and the exhaust pipe in the smoke box. This exhaust pipe flexible connection is likewise provided with a slip joint to

allow for the variations in its length when the engine rounds a curve. The construction of these flexible connections is shown in Fig. 11.

As will be noticed, the ball joints consist of a ball-bearing, gland, stuffing box and packing, while in the slip joints the construction is very much the same, without the ball-bearing.

The packing in both classes of joints consists of a fiber material. The free nominal size of the packing rings is five-eighth inch square in section and they are hammered and worked down to one-half inch square before being applied, which makes them soft and pliable.

In the case of the receiver pipe joint at the high pressure cylinders, a brass ring of elongated diamond section is inserted in the center of the packing. As this ring is just the width of the packing space it seals all the joints in the packing rings proper and forces them tightly against the inside of the box and against the ball.

In repacking the joint this brass ring should be removed, all the packing rings inspected, new rings put in where necessary and the ring put back in its proper place. In every case the original arrangement of joint packing should be preserved.

The diagram in Fig. 11 shows the method of arranging the rings. These must be cut to the correct lengths and the two ends in every case meet perfectly when in place. They are so arranged that the seams in any two adjacent rings are at least a quarter of a circle or 90 degrees apart, and all the seams in the entire set are at

least one-eighth of a circle or 45 degrees from each other. The reference numbers on the diagram correspond to those on the packing drawings.

It is important, therefore, when the packing is

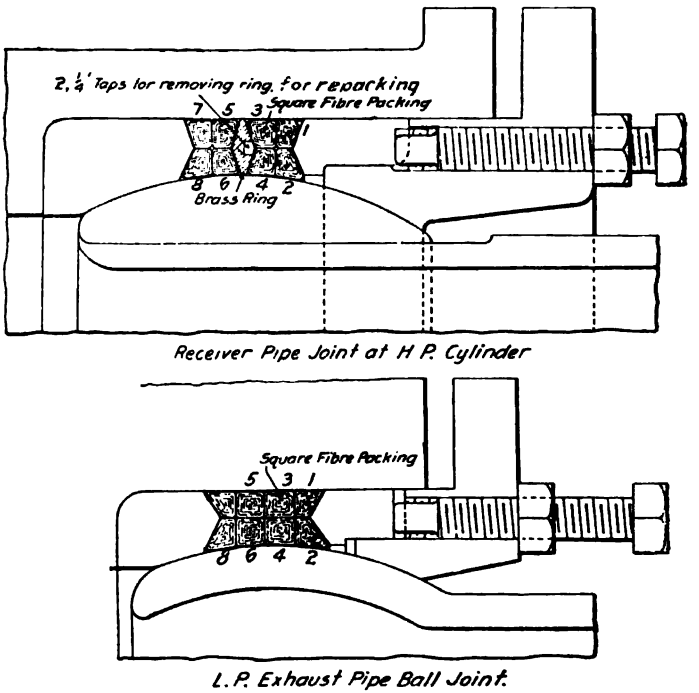

2, ¼" Taps for removing ring, for repacking
Square Fibre Packing
7 5 3 1
8 6 4 2
Brass Ring
Receiver Pipe Joint at H P. Cylinder
Square Fibre Packing
5 3 1
8 6 4 2
L.P. Exhaust Pipe Ball Joint.

FIG. 11. FLEXIBLE JOINTS.

renewed that care should be taken to arrange them in the manner shown, since if so arranged trouble from leaky joints will be avoided.

It is also essential that in renewing packing

the same kind of packing should be used as that originally applied.

Owing to the fact that in the articulated compound locomotive a long receiver pipe is generally employed and the ball joint is located in the vertical center of the pivot connection between the

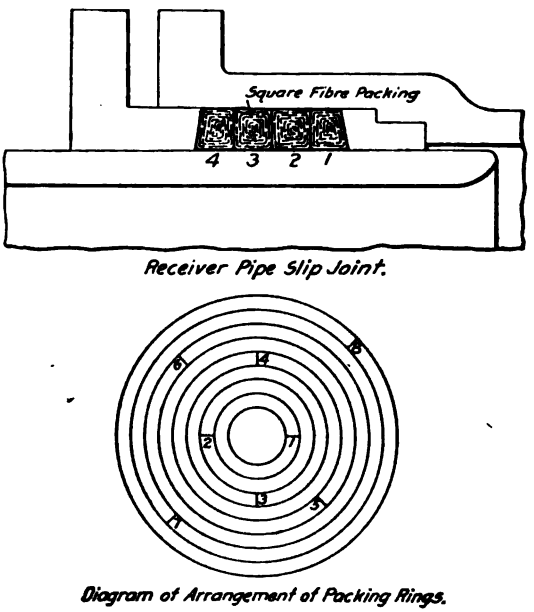


FIG. 11. FLEXIBLE JOINTS.

front and rear engines, there is very little movement in the ball joint and there is practically no tendency for this joint to leak.

In case there is any leakage it is usually due to the fact that the gland is not screwed in tight

enough, and can be easily stopped by a turn or two on the gland bolts.

ADJUSTMENT OF THE ALIGNMENT OF THE FRONT ENGINE FRAMES.

In locomotives of the articulated compound type vertical hanger or "trim" bolts X, Fig. 12, connect the upper rails of the rear frames with the lower rails of the front frames. These bolts have ball and socket bearings in the frame rails and sufficient play is allowed in the bolt holes to provide for the lateral movement of the front frames when the locomotive is passing through a curve. They serve to adjust the weights on the front and rear engines so that each bears its proportionate amount of the total load, and to keep the front frames in proper alignment. Ordinarily, therefore, the alignment of the engine may be easily adjusted if necessary by means of them without any other change in the spring rigging.

In designs of articulated compound locomotives having no front truck, where two sliding boiler bearings are employed, the front sliding bearing does not normally carry any load, but is merely an emergency stop in case of derailment or any unusual change in the alignment between the two frames. This bearing is so designed that when the front and rear frames are in proper alignment there is a clearance (ordinarily ¼ inch) between the upper and lower bearing and an equal amount between the upper bearing and the safety straps or clips, as indicated at Z and Z', Fig. 12.

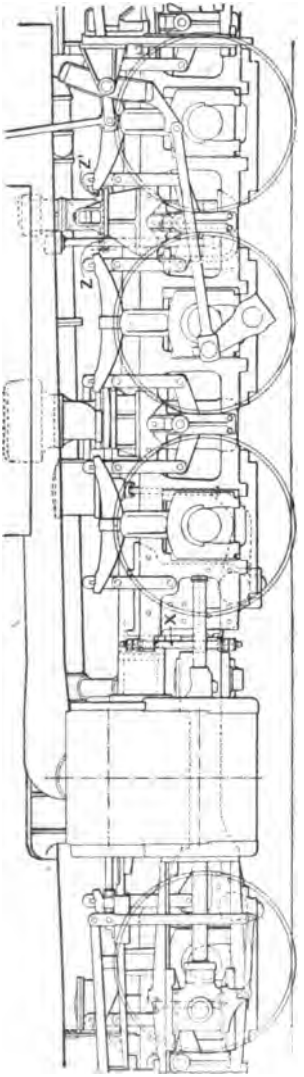


FIG. 12. FRONT DRIVING SPRING SYSTEM.
Showing "Trim" Bolts and clearances allowed at the forward boiler bearing in 0660 and 0850 types of locomotives.

An exception to the above rule should be noted in the case of class 0880 engines designed for over 16-degree curvature. In such designs the front bearing may sometimes be used for supporting a small part of the weight on the front engine, though a considerably less amount than when a front truck is used.

About ¾-inch total play is also always allowed between the rear draw casting (or jaw) and the front draw casting (or hinge) of the articulated connection. The hinge casting should not touch either the top or bottom of the jaw.

In the case of this articulated compound locomotive of one of the designs covered in the above rule, if the hinge casting of the articulated joint bears on the top of the jaw and the safety strap, or clips, of the front sliding boiler support bears close against the upper casting of this support, adjustment may be made by the "trim" bolts, which should be tightened up until the vertical play is approximately divided in each case.

On the other hand, if the bearing surfaces of the upper and lower castings of the front sliding support touch and the articulated hinge bears on the bottom of its jaw, adjustment should be made by loosening the "trim" bolts.

Should the upper and lower bearings of the front boiler support touch, while at the same time the articulated hinge bears on its top surface against the jaw, a liner plate of a thickness of about one-half the total play should be inserted between the sliding block of the rear boiler support and its saddle. This should give a satisfac-

tory adjustment. To insert this liner, the rear bearing can be raised the required amount by tightening up the vertical suspension or "trim" bolts X, while the plate is fitted in, after which the nuts on the bolts should be eased off till the correct tension is secured and the proper adjustment is sure to be obtained.

If, on the other hand, the safety straps, or clips, bear on the upper casting of the front sliding boiler support and the articulated hinge bears on its bottom surface against its jaw, the sliding block of the rear sliding boiler support should be planed off an amount equal to one-half the total play.

When front trucks are used or where both bearings of the front engine support weight, the "trim" bolts are provided with a spring under the nut at one end in order to relieve the excessive load, which is liable to be concentrated on the rear bearing because of inequalities in the level of the track, or similar conditions.

BREAKDOWNS.

In case of any breakdown in which one or more of the cylinders can be disconnected and the locomotive run in with the remaining cylinders active, simply throw the emergency operating valve N in the cab into the simple position and proceed as with a simple locomotive, namely, disconnect and block the disabled cylinder or cylinders. This is the only rule to follow and the only one to be

remembered, and covers all cases of accidents which do not entirely disable the locomotive.

OPERATING RULES.

Always open the cylinder cocks in starting.

Usually the locomotive will start the train when the throttle is opened in the ordinary way with the reverse lever in the position required for the weight of the train or ordinarily in the extreme notch. If the locomotive fails to start the train when operated in this way, change it into simple working by turning the handle of the emergency operating valve in the cab so that it points to the *rear*. This same course should be followed if the engine is about to stall on a heavy grade. If the speed is over three or four miles an hour, no increase in power will be obtained by changing the locomotive into simple working.

When drifting, the reverse lever should be kept at ¾-stroke or more. As before stated, if this is done, the locomotive will drift freely.

The oil cylinder of the power reversing gear should always be kept full of oil. The piston and piston rod packing of the oil cylinder should be kept in good condition so as to prevent leakage. If the reversing gear operates too rapidly it indicates that there is not sufficient oil in the oil cylinder and this should be refilled and the leakages stopped.

If the reversing gear is not adjusted properly so that the latch of the main reverse lever does not engage with the teeth of the quadrant, the

trouble should be remedied as soon as possible. If not properly adjusted, the locking of the reverse gear will be put almost entirely on the latch of the auxiliary lever, which is not designed for such duty and would, therefore, quickly wear.

The by-pass valves should be taken out and cleaned periodically to prevent them from being gummed and sticking. When the locomotive is first put into service, these valves should be cleaned quite frequently for a few times so as to keep them free from the core sand which is sure to work into them. Afterwards they will require only ordinary attention to work properly. When these valves are properly performing their functions, the locomotive will drift freely. If they stick open it will cause a severe blow, while if stuck in the closed position, it will cause a pounding in the low pressure engines.

The relief valves in the low pressure steam chests should be tested occasionally to see that they are correctly set at 45 per cent of the boiler pressure, as these valves relieve any excessive pressure in the steam chests.

Repairs to Flexible Joints.—In renewing the packing of the flexible joints the same kind of packing should be used as that originally applied. Also care should be taken to keep the arrangement of the packing the same as that shown in the diagram in Fig. 11.

The brass ring of the receiver pipe joint at the high pressure cylinder may be removed in order to insert new packing, but the original arrange-

ment of the joint packing should always be preserved.

LUBRICATION.—Give the intercepting valve a liberal feed of oil for a minute before starting and occasionally during long runs, when the throttle is not shut off for a considerable length of time. Except for this, one drop of oil to the intercepting valve every four or five minutes is ample when running.

Besides the intercepting valve, the other parts of the articulated compound locomotive which should be oiled, which are not found on the ordinary locomotive are:

Sliding boiler bearings on the front engine.

The ball joint in front of the high pressure cylinder (*before starting on a trip*).

The upper or rear ball joint of the exhaust pipe (*before starting on a trip*).

The lower or front ball joint of the exhaust pipe (*before starting on a trip*).

The bolt connecting the two engines.

The ball bearings of the vertical suspension or "trim" bolts which connect the upper rails of the rear frames with the lower rails of the front frames X, Fig. 12.

The ball bearings of the floating columns (if applied).

The piston rod packing of the cylinders of the power reversing gear.

The air cylinder of the power reversing gear, by means of the plug in the top of the cylinder (*about once a week*).

BLOWS.—To test for blows in the valves or pis-

tons, throw the emergency operating valve in the cab to the simple position, namely, with the handle pointing to the *rear*. Spot the locomotive and test the same as a simple locomotive.

NOTE.—The Author is Indebted to The American Locomotive Company for the Foregoing Full and Authoritative Description.

Mallet Articulated Compound Locomotive (Baldwin Locomotive Company).—As the distinctive features of the Mallet locomotive have been described, the articulated boiler connection which does not form a part of that locomotive is given here, also the arrangement of the superheater and reheater.

The flexible boiler connections used on the two following engines are entirely different in construction, engine 1158 having a double ball-jointed connection, while engine 1159 has a pleated or bellows form of connection.

On engine 1158 the connection consists of two cast iron sleeves, Fig. 2, fitted one within the other and provided with snap rings to keep the joint tight. Each sleeve forms a ball joint with a cast iron ring, which is bolted to the shell of the corresponding boiler section. These rings are made in halves, to facilitate assembling. The ball joints are kept tight by rings of soft metallic packing, which can be adjusted by set screws. The two boiler sections can thus move in any direction relative to one another and full provision is made for expansion and contraction.

On engine 1159 the joint is composed of sixty rings of high carbon steel having a thickness of No. 14 wire gauge, Fig. 3. These rings are ten inches wide and have an outside diameter of sev-

FIG 1 LOCOMOTIVE WITH FLEXIBLE BOILER BELLOWS TYPE OF CONNECTION

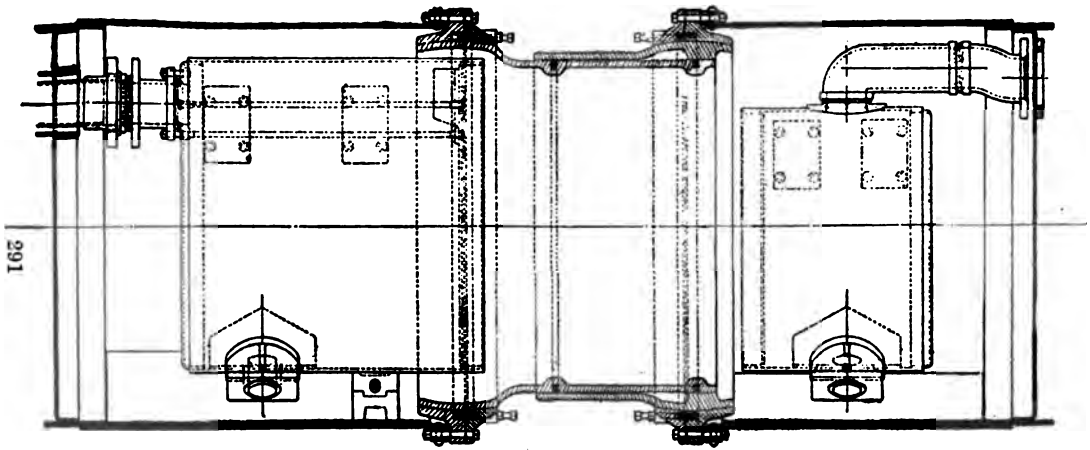


FIG 2 LONGITUDINAL SECTION, SHOWING DOUBLE BALL-JOINTED BOILER CONNECTION AND ARRANGEMENT OF SUPERHEATER AND REHEATER

enty-five and one-half inches. They are made with a set, so that, when placed adjacent to each other, they form a series of V-shaped joints. The adjacent rings are riveted together at the inside and bolted at the outside, and the connection is bolted in place between the front and rear boiler sections. The products of combustion traverse the flexible connection through a cylindrical flue forty-four inches in diameter. This flue is riveted to the rear boiler section and prevents cinders from lodging in the crevices between the connecting rings.

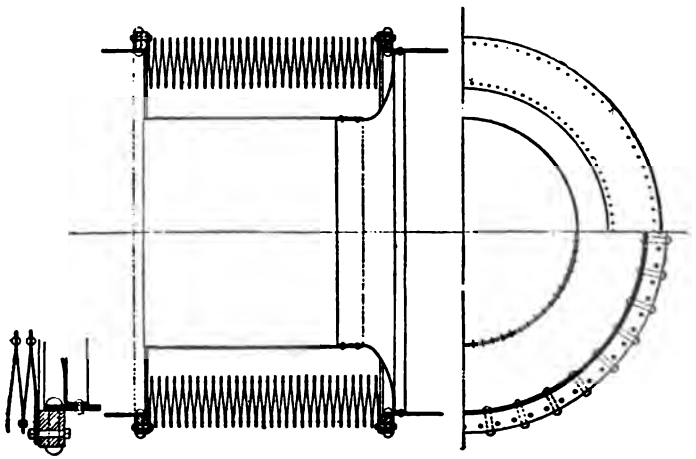


FIG. 3 LONGITUDINAL AND TRANSVERSE SECTIONS SHOWING BELLOWS TYPE OF BOILER CONNECTION

To assist in holding the boiler sections in alignment, a centering device is placed on each side on the horizontal center line of the boiler. This arrangement consists of a pair of helical springs,

which are seated in cast steel brackets riveted to the shells of the front and rear boiler sections, Fig. 4. The springs are held in place between washers, carried by a horizontal thrust bar. When the engine enters a curve, the two boiler sections assume an angular position with reference to each other and by reason of the compression of the springs on the outer side the corresponding thrust bar is thrown into tension, thereby tending to bring the boiler sections back into alignment.

It is, of course, necessary in these locomotives to place flexible joints in all pipes which pass the

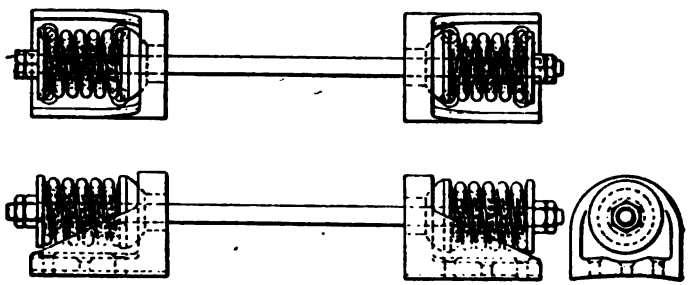


FIG. 4 CENTERING DEVICE USED ON FLEXIBLE BOILER LOCOMOTIVES

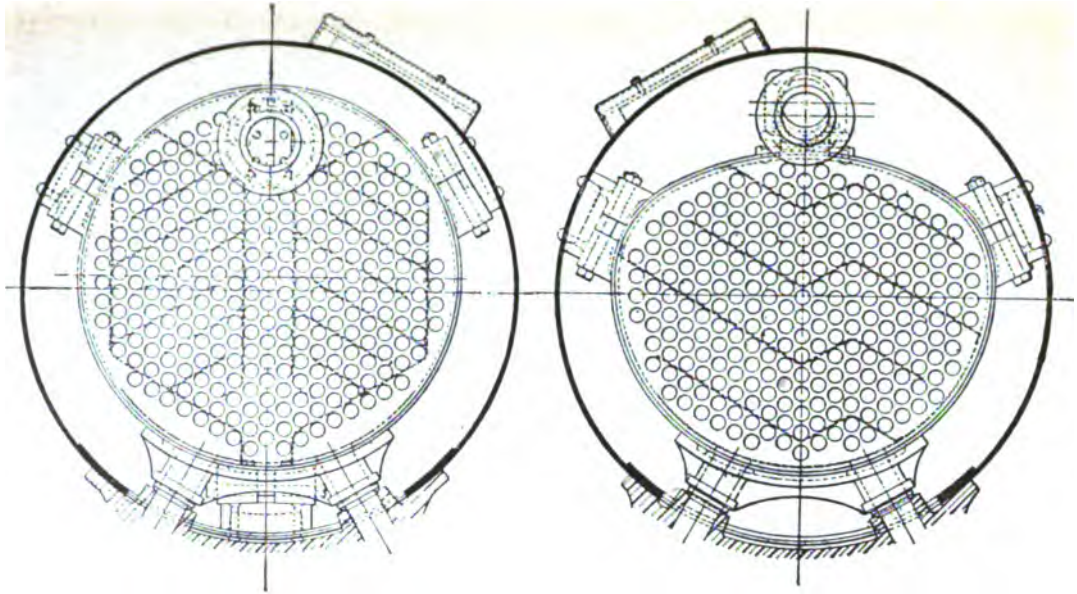
articulated connections in the frames and boiler. This, however, introduces no objectionable complication. The steam piping is simplified, as no flexible joints are required in the exhaust connection between the low-pressure cylinders and the smoke box. There is claimed to be a distinct advantage in the avoidance of sliding supports under the forward boiler section and the stability of the locomotive, when on curves, is not impaired by the

lateral displacement of the boiler on the front frames, which necessarily occurs in the Mallet locomotive as usually built.

The arrangement of the superheater and reheater is practically the same on both engines. An open chamber is located in each boiler section adjacent to the flexible connection and these chambers contain the heaters, Fig. 5. The superheater is located in the rear boiler section and the reheater in the front section. These heaters are of the Jacobs type and each consists of a steel drum traversed by horizontal fire tubes.

The superheater is exposed to a higher temperature and steam pressure than the reheater and its tubes are welded at each end, while in the reheater the tubes are rolled and beaded. The heaters are fitted with internal baffle plates, so that the steam is compelled to follow a circuitous course among the tubes.

The throttle valve is connected with the superheater by an internal dry pipe and the steam enters the superheater at the top. There are two outlets, placed right and left in a steel casting on which the superheater drum is seated, and these outlets communicate directly with suitable passages which are cored in the high-pressure cylinder saddle. The connections between the saddle and steam chests are effected by short elbow pipes.



REHEATER SUPERHEATER

FIG 5 TRANSVERSE SECTIONS OF FLEXIBLE BOILER, SHOWING ARRANGEMENT OF SUPERHEATER AND REHEATER

FIG. 6 Mallet Articulated Locomotive with Double Ball-jointed Boiler

DICKSON COMPOUND.

The Dickson Locomotive Works[1] compound is built under the Dean patents which cover special valves both for automatic and for convertible compounds, but, inasmuch as the practical information is based on the mechanism for the former class only, the detailed description will be confined to the automatic compound.

The starting and intercepting valves are placed on top of the high-pressure steam chest on the right side of the engine. Upon opening the throttle for starting, live steam is admitted to both cylinders, but, after a stroke or two, the intercepting valve automatically opens and the engine works compound thereafter.

The high-pressure exhaust port Q (Fig. 79) is in the balance shield of a Richardson balanced valve P, having its top removed, and thus the exhaust steam from the high-pressure cylinder passes up through it and the intercepting valve G to the receiver and low-pressure cylinder, when the intercepting valve G is open. Beneath the seat R, intercepting valve G, is a port E^1 leading to the chamber E.

The receiver, as usual with cross-compounds, is located in the smoke-box, but its shape is out of the ordinary. It is made very large and, between its connections with the high and the low-pressure saddles, branches into two forks, each of which is oval and has metal ribs lengthwise with the pipes. Fig. 80 shows a section through this

double portion of the receiver. The object of the designer has been to obtain a very large heating surface, so as to re-evaporate some of the water

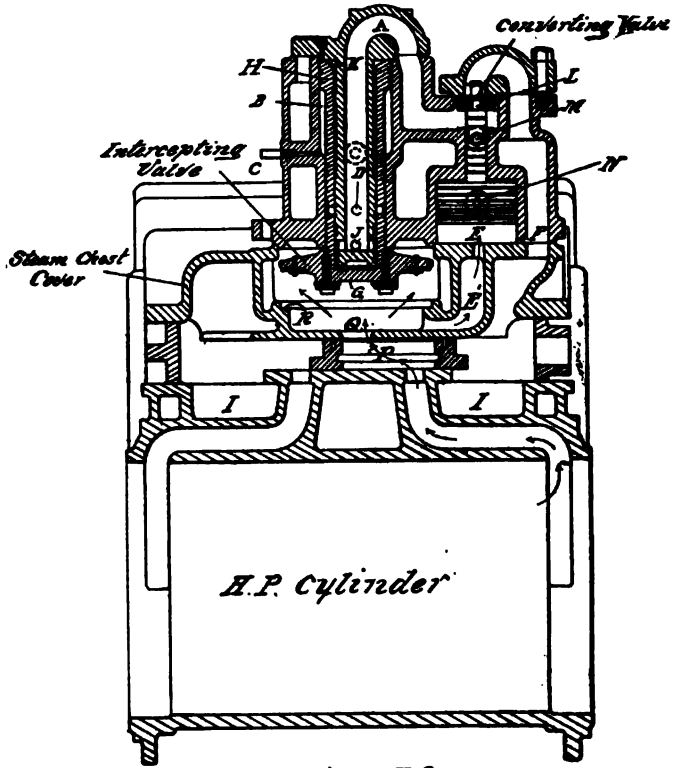


Fig. 79.

Dickson Compound.

condensed in the high-pressure cylinder as it passes with the exhaust steam through the receiver to the low-pressure side. From the re-

ported economy of these engines, it would seem that the object has been largely attained.

Referring to Figs. 79 and 81, it will be seen that the intercepting valve *G* is fastened to the annular stem *H* having an enlarged top above the space *B* which is constantly filled with air pressure or live steam from the pipe *C* when the engine throttle is open, and hence sleeve *H* will be found at the top of its travel, as illustrated, after the engine has started.

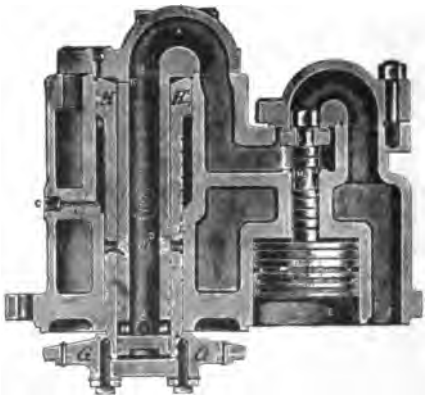
The operation is as follows: Open the throttle for starting and live steam enters the high-pressure steam chest from the induction ports *I*

Fig. 80.

(Fig. 79) as usual and besides has a connection to *F* through the top of the steam chest, as shown. There being no pressure in the receiver (to which chamber *E* is connected through the open intercepting valve *G*), the weight of *N* will have caused the converting valve *L* to drop down, and thus the live steam passes through valve *L* into the tube *AJ*. Port *K* admits steam to the enlarged top of the annular stem *H*, forcing the intercepting valve *G* down on its seat *R* and bringing the ports *D* in the stem *H* opposite the ports *J* of the central steam tube *A*, thus admitting live steam through them to the

receiver and low-pressure steam chest. With the intercepting valve *G* closed (down), the first high-pressure exhaust, acting in chamber *E* through the port E^1, causes piston *N* to lift and close the converting valve *L* (as shown in Figs. 79 and 81), thereby shutting off the supply of steam from *F* to the central tube *AJ*. What

Fig. 81.



Dickson Compound
Starting Valve in position, working Compound

steam remains in this tube escapes through the relief port *M* and allows the intercepting valve *G* to move up (open) by live steam pressure from the pipe *C* acting in the annular cavity *B*, as hereinbefore described, assisted by the high-pressure exhaust below *G*. The engine then works compound, as live steam is shut off from

the low-pressure cylinder and the exhaust from the high-pressure cylinder takes its place.

The engine above described is an automatic compound, that is, starts with live steam in both cylinders but after the first stroke changes automatically to compound.

The inventor of this system, in a design not shown, introduces a reducing valve in the central tube *A* and adds a separate exhaust valve operated by live steam from a three-way cock in the cab, thus making a compound of the convertible class, but at the same time he does not advise convertible construction in compounds.

Accidents to Dickson Compounds.—What should be done in order to run the engine in with the low-pressure side only? Nothing different from a simple engine, but the boiler pressure carried should be reduced about one-half or else the engine throttle opened very slightly.

How could the engine run with the high-pressure side only? There being no means of exhaust except into the receiver, the low-pressure valve would have to be placed so as to uncover the exhaust port or, if that were found to be impossible, the valve entirely removed.

The type of compound locomotive built by the Rhode Island Locomotive Works is sometimes known as the "Batchellor" system, that being the name of the inventor of the device.

In the saddle of the low-pressure cylinder on the left side of the locomotive is located an intercepting and a reducing valve and in the smoke-box a separate high-pressure exhaust valve. When the throttle is opened, the engine starts with live steam in both cylinders. With the separate exhaust valve closed the engine automatically changes to compound in the course of a complete revolution; with it open, the engine continues to work as a simple engine as long as desired. This separate exhaust valve is operated at the will of the engineer by means of a three-way cock in the cab; and thus the engine belongs to the class of convertible compounds.

Fig. 82 shows a vertical section lengthwise through the intercepting valve, with the latter in the position when the engine is either starting or being run as a single-expansion locomotive. Fig. 83 shows the same section with the intercepting valve in compound position. *R* is the receiver port; *S* is a connection from the main steam pipe; *L* is a port leading to the low-pressure steam chest, and *B* is a reducing valve. The intercepting valve is composed of the four pistons, *1*, *2*, *3* and *4*, of which the last works in an oil dash-pot *C*.

If the engine had stopped after running compound with the valve, as in Fig. 83, and the engine throttle were then opened, live steam from the pipe *S* would force the intercepting valve into simple position as shown in Fig. 82, because piston *2* is larger than piston *1*. In this latter position small port *D* is open and steam from *S* passes through it and the reducing valve *B* to the low-pressure side. Piston *3* has now closed the communication with the receiver *R* in which one

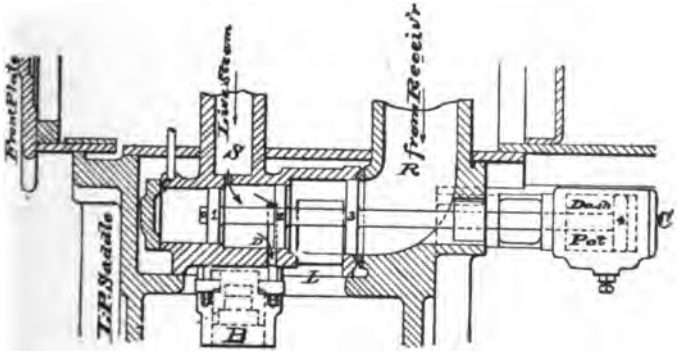


Fig. 82.
Rhode Island Compound Engine Working Simple.

or two exhausts from the high-pressure cylinder soon produces sufficient pressure to react on this piston *3*, bearing the intercepting valve to the left against the differential pressures on pistons *1* and *2* acting in the opposite direction, and the valve is shifted to compound position, as in Fig. 83, in which position no more live steam can pass through port *D* to the low-pressure side, and

the receiver R is connected through port L with the low-pressure steam chest, for which it forms the supply thereafter, as indicated by the arrows.

The port leading from the live steam supply S into the intercepting valve, is larger than it appears from the illustrations, as it extends partly around the circumference of the valve.

The separate exhaust valve shown in Figs. 84 and 85 is placed on the receiver in the smoke-

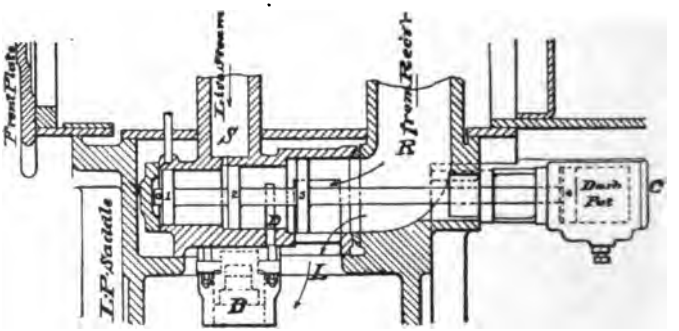


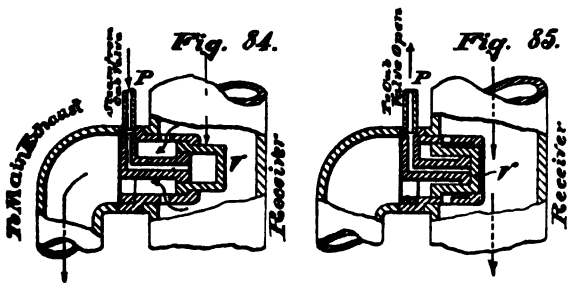
Fig. 83.

Rhode Island Compound
- Engine Working Compound -

box and, when opened by pressure through pipe P leading from a three-way cock located in the cab and under the control of the engineer, connects the receiver with the main exhaust pipe. The opening of this valve will thus permit the high-pressure exhaust to escape and there will be no accumulation of pressure in the receiver. Hence, from the previous explanation, it will be seen that the intercepting valve remains in sim-

ple position (Fig. 82) until such time as the engineer closes the separate exhaust valve, when a stroke of the engine automatically changes the mechanism to compound position, as before described when starting.

The operation of the separate exhaust valve, shown in Figs. 84 and 85, is very simple. Pressure admitted from the cab through pipe *P*, moves the valve *V* from its closed position (Fig. 85) to the right and vents the receiver pressure direct to the exhaust pipe, as indicated by the



Open-Engine Working Simple. Closed-Engine Compound.

Rhode Island-Separate Exhaust Valve

arrows, Fig. 84. Withdrawing the pressure from the pipe *P*, allows the receiver pressure to automaticaliy move and hold closed the valve *V*, as in Fig. 85.

Accidents to Rhode Island Compound.—If it became necessary to disconnect either side, how should the engine be run? Disconnect properly, observing the same precautions advised for simple engines, then open the separate exhaust

valve so that no pressure can accumulate in the receiver.*

What would you do with a broken intercepting or reducing valve? Open the separate exhaust valve and run with very light throttle, or, preferably, carry a reduced boiler pressure.

Would the working of the engine be affected if the separate exhaust valve *V* were broken? Probably not; but, if it left an opening between the receiver and the exhaust, the engine would run as a simple locomotive only.

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*As remarked elsewhere in relation to designs having a separate exhaust valve, if it were the high-pressure side that was disconnected, it would not be necessary to open the separate exhaust valve unless there was some leakage of steam into the receiver.

THE FOUR CYLINDER BALANCED COMPOUND LOCOMOTIVE.

In the evolution of the compound locomotive a style known as the "Four-Cylinder Balanced" has been successfully adopted by several of the great American railways. Of this style of locomotive there are three types in use, known as the "Vauclain," "Cole" and "DeGlehn," the characteristics of which are shown in the following table:*

TYPE. LOCATION OF H. P. CYL.

Vauclain—Inside in line with L. P.
Cole—Inside and in front of L. P.
DeGlehn—Outside in line with L. P.

MAIN ROD CONNECTION.

Vauclain—Outside, front driver; inside, front axle.
Cole—Outside, rear driver; inside, front axle.
DeGlehn—Outside, rear driver; inside, front axle.

VALVE ARRANGEMENT.

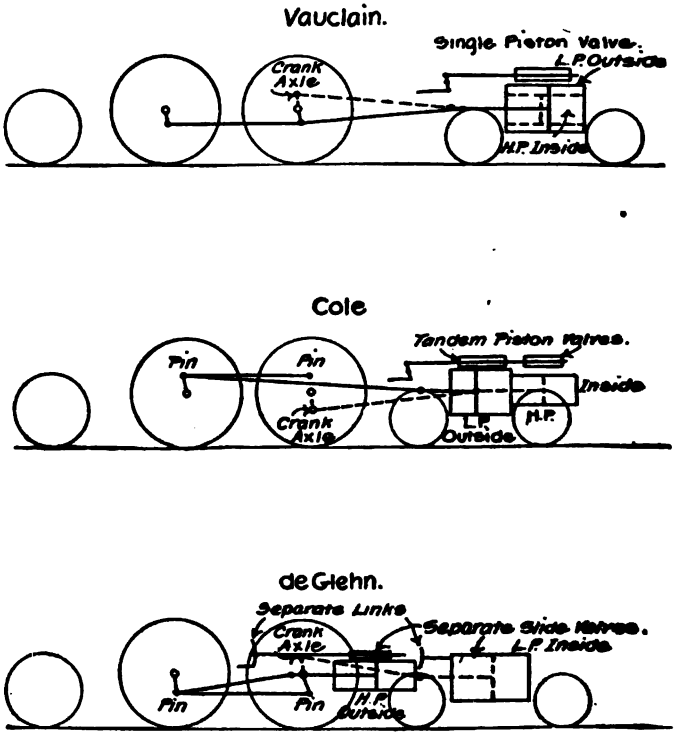
Vauclain—Two, piston. One for each pair of low and high pressure cylinders.
Cole—Four, separate piston tandem arrangement. H. P. and L. P. on same stem on each side.
DeGlehn—Four, separate slide, separate valve gear. Two reverse levers.

VALVE MOTION.

Vauclain—Stephenson; two links.
Cole—Stephenson; two links.
DeGlehn—Walscheat (modified); four links.

It will be noted that each of these types has certain features in common with one or more of the others. The comparison shown in the following sketch will make the points of distinction and similarity more clear.

*There is yet a fourth type of four-cylinder compound locomotive known as the "Von Borries," but it has not been adopted by American railways.



The "*Vauclain*" type has high pressure cylinders inside and low pressure cylinders outside, all in the same horizontal plane in line with the smoke box, and all driving the front driving axle. A single piston valve worked from a single link motion effects the steam distribution for the pair of cylinders on each side. The advantages claimed for the "Vauclain" type are simplicity of valve mechanism and location of cylinders re-

quiring the least deviation from Standard American practice and balanced reciprocating parts.

The *"Cole"* type has high pressure cylinders inside, in advance of the smoke box, driving the front driving axle. The low pressure cylinders are outside in line with the smoke box, driving the rear driving axle. Two piston valves on a single stem serve the steam distribution for each pair of cylinders, and each valve stem is worked from an ordinary link motion. The advantages claimed for the "Cole" type are distribution of cylinder effort between driving wheels, simplicity of valve motion while providing separate valves for high and low pressure cylinders, perfect balance for reciprocating parts and compliance with American requirements for location of cylinders calling for insignificant changes in other parts of the machine.

The *"De Glehn"* type has high pressure cylinders outside and behind the smoke box, driving the rear drivers. The low pressure cylinders are inside under the smoke box, and drive the crank axle of the front drivers. Four separate slide valves and four Walschaert valve gears allow of independent regulation of the high and low pressure valves. The advantages claimed for the "De Glehn" type are distribution of crank effort, proper steam distribution in high and low pressure cylinders due to separate valve mechanisms and reverse levers, a perfect balance for reciprocating parts and protection against condensation by inside location of low pressure cylinders.

In the balanced compound locomotive only the revolving weights are considered as the reciprocating parts move to and fro, balancing each other, and have no effect on the rail. The method

employed by one of the largest locomotive builders of the world in determining the position and weight of each counterbalance is as follows.*

The revolving weights are concentrated at two points on each side of the engine; that is, at the centers of gravities of the outside pins and of the inside crank pins. These weights are made up (Fig. 86) as follows:

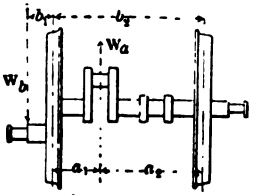


FIG 86

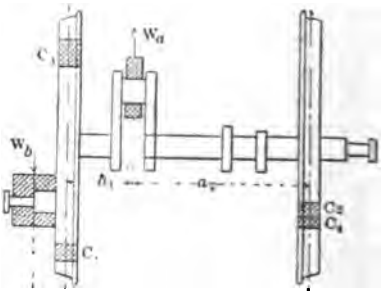


FIG 87

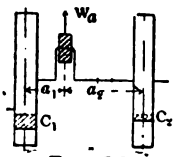


FIG 88

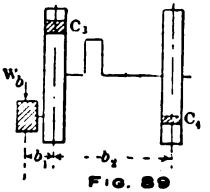


FIG. 89

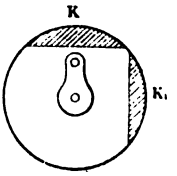


FIG 90

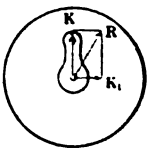


FIG 91

FIG 92

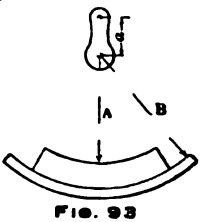


FIG. 93

*The Baldwin Locomotive Works.

(a) Weights concentrated at each inside crank pin, composed of two crank cheeks, inside crank pin, back end of main rod. These weights will be known as W_a.

(b) Weights concentrated at each outside pin, composed of wrist pin, wrist pin hub, front end of side rod and, if so coupled, the back end of the main rod. These weights will be known as W_b.

The throw of the weights W_a is balanced by two weights, one in each wheel, throwing in the opposite direction to the crank weights and of such magnitude that the three parallel forces thus produced shall balance each other, any one being, therefore, equal and directly opposed to the resultant of the other two. The throw of the weights W_b is balanced by a weight in the wheel on the same side throwing in the opposite direction, and by one in the opposite wheel throwing in the same direction, the respective weights being of such magnitude that the system of parallel forces so produced shall balance each other.

From the above it will be seen that in the left wheel the counterweights which balance the revolving weights of the right side are at 90 deg. to those which balance the revolving weights of the left side of the engine. In each wheel there will, therefore, be two counterweights, one opposite the inside crank and one at right angles. These two weights can be combined by either graphical or analytical methods.

In Fig. 87 let W_a — weights of inside crank pin.

W_b — weights at outside crank pin.

a_1 and a_2 — distance of centers of gravities of counterbalances from W_a.

b_1 and b_2 — distance of centers of gravities of counterbalances from W_b.

The weights C required in left wheel (Fig. 88) to balance W_a $C_1 \times (a_1 + a_2) = W_a a_2$

$$C_1 = \frac{W_a a_2}{a_1 + a_2}$$

the weight C_2 in the right wheel being

$$C_2 = \frac{W_a a_1}{a_1 + a_2}$$

These two weights throw in the opposite direction to W_a. The weight C_3 required in the left wheel (Fig. 89) to balance outside weights W_b.

$$C_3 b_2 = W_b (b_1 + b_2)$$

$$C_3 = \frac{W_b (b_1 + b_2)}{b_2}$$

This weight is opposite to the pin. The required weight C_4 in the right wheel being

$$C_4 \times b_2 = W_b b_1$$

$$C_4 = \frac{W_b b_1}{b_2}$$

This weight throws in the same direction as the weights W_b.

Since W_a and W_b are 180 deg. apart, the counterweights to balance them in the left wheel will likewise be opposed to each other, the actual weight to use will therefore be

$K - C_3 - C_1$.

The weights in the left wheel which balance the revolving weights on the right side both throw in the same direction and at 90 deg. from the

weights just determined, therefore, a second weight (Fig. 90)

$K_1 = C_2 + C_4$

must be placed 90 deg. from the above.

These weights can be combined either analytically or graphically, and both their magnitude and direction determined by the usual method of scaling two lines at right angles to each other, their length being proportionate to the counterweights completing the parallelogram, the diagonal of which will give both the size of the resultant weight and the angle at which it should be placed.

It can also be determined analytically (Fig. 91):

$$R = \frac{1}{K}\sqrt{K_2 K_1^2}$$

and $\frac{}{K_1}$ = tangent of the angle.

To this point the weights can be considered as acting at a radius equal to the crank arm. The weight at the rim of the wheel can be calculated irrespective of the diameter of the wheel (Fig. 92).

$$\text{Chord A B} = \sqrt[3]{\frac{12\ R\ a}{t\ q}}$$

R — Known weight at crank pin radius a.

t — Thickness of counterbalance.

q — Weight of cu. in. of metal.

In applying the formula the thickness should be assumed. The sector balance (Fig. 93) can be calculated as follows:

$$A = \sqrt[3]{B^3 - \frac{8\ R\ a}{2\ t\ q\ \sin\frac{180\ M}{n}}}$$

B — Outside radius.
A — Inside radius.
n — Number of spokes.
M — Spaces to be filled by balance.

Following will be found details and drawings of locomotives that have been constructed and put in operation of each of the three types mentioned.

VAUCLAIN FOUR-CYLINDER BALANCED COMPOUND.*

This locomotive is of the four coupled type. Its construction is illustrated in drawings Figures 94 to 100. The tractive power is 24,000 lbs. when working as a compound, and the cylinders are approximately equivalent to 18.9 in. simple cylinders. The weight on the drivers is 90,000 lbs., but with the balanced construction it is claimed a much greater weight than this can be placed on these wheels without injury to the track than would be caused by a locomotive of usual system of counterbalancing. The boiler is of the wide firebox type for coal burning. The mud ring is 5 in. wide at the sides, to assist circulation. The main bearings are $11\frac{1}{8}$x10 in., the crank pins 10x4 in., the wheel fits 10x$8\frac{5}{8}$ in. and the crank webs 20 in. wide by 5 in. thick.

The method of balancing and the light weights employed are clearly indicated in the drawing of the driving wheels, Fig. 96. A summary of the revolving weights is as follows:

REVOLVING WEIGHTS.

Pin No. 1. Inside. Pounds.	Pin No. 2. Outside. Pounds.	Pin No. 3. Pounds.
403	423	...
588	180	153
88	214	174
...	148	148
1,079	965	475

This leaves 1,079, minus 965, or 114 lbs. excess revolving weight on the inside of the main wheel. The reciprocating weights are as follows:

*This engine was built by the Baldwin Locomotive Works for the Atchison, Topeka & Santa Fe Ry., 1903.

RECIPROCATING PARTS.

	Inside.	Outside.
Piston	356	463
Crosshead	310	310
Main rod on crosshead pin	149	156
Totals	815	929

This leaves 929, minus 815, or 114 lbs. of reciprocating weight in the main wheel. The 114 lbs. of reciprocating weights are balanced in the main wheel by 114 lbs. excess revolving weight inside the main wheel, thus requiring no counterbalance in that wheel. The balance for 475 lbs. is required in the rear wheel and this is accomplished by a weight of 208 lbs. with a radius of 28½ in., as indicated in the diagram.

RATIOS AND DIMENSIONS.

Heating surface to volume of high pressure cylinders, = 571.
Tractive weight to heating surface, = 29.7.
Tractive weight to tractive effort, = 3.75.
Tractive effort to heating surface, = 7.92.
Heating surface to grate area, = 61.3.
Tractive effort X diameter of drivers to heating surface, = 578.
Heating surface to tractive effort, = 12.6 per cent.
Total weight to heating surface, = 61.7.
Gauge, 4 feet 8½ inches.
Cylinder, 15 and 25x26 inches.
Valve, balance piston.
Boiler—Type, wagon top.
Diameter, 66 inches.
Thickness of sheets, 11-16 and 13-16 inch.
Working pressure, 220 pounds.
Fuel, soft coal.
Staying radial.
Firebox—Material, steel.
Length, 107 15-16 inches.
Width, 66 inches.
Depth, front, 75⅞ inches; back, 67⅜ inches.
Thickness of sheets, sides, ⅜; back, ⅜; crown, ⅜; tube, 7-16 inch.
Water space, front, 4½ inches; sides, 5 inches; back, 4 inches.
Tubes—Material, iron, wire gauge No. 11.
Number, 273; diameter, 2¼ inches; back, 4 inches.
Heating Surface—Firebox, 190 square feet.
Tubes, 2,839 square feet.
Total, 3,029 square feet.
Grate area, 49.4 square feet.

Driving Wheels—Diameter outside, 73 inches.
Diameter of center, 66 inches.
Journals, main, 10x11 inches; others, 9x12 inches.
Engine Truck Wheels—Diameter, 34¼ inches.
Journals, 6x10 inches.
Trailing Wheels—Diameter, 44 inches.
Journals, 8x12 inches.
Wheel Base—Driving, 6 feet 4 inches.
Rigid, 15 feet.
Total engine, 29 feet 6 inches.
Total engine and tender, 58 feet 3½ inches.
Weight—On driving wheels, 90,000 pounds.
On truck, front, 52,000 pounds.
On trailing wheels, estimate, 45,000 pounds.
Total engine, 187,000 pounds.
Total engine and tender, about 327,000 pounds.
Tank capacity, 8,400 gallons.
Tender—Wheels, No. 8; diameter, 34¼ inches.
Journals, 5½x10 inches.

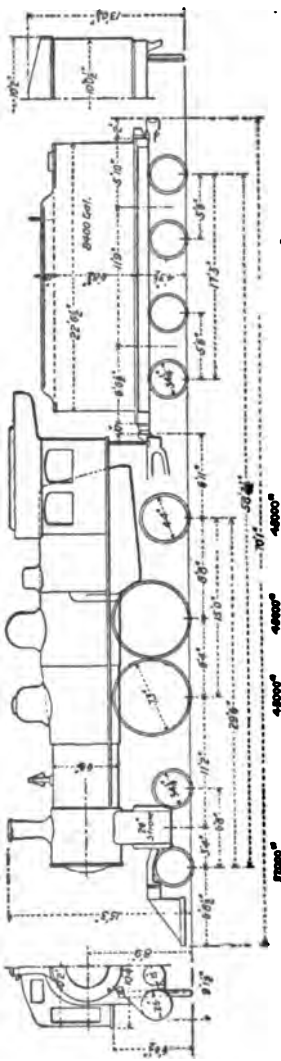


Fig. 84.—DIAGRAM OF LOCOMOTIVE AND TENDER

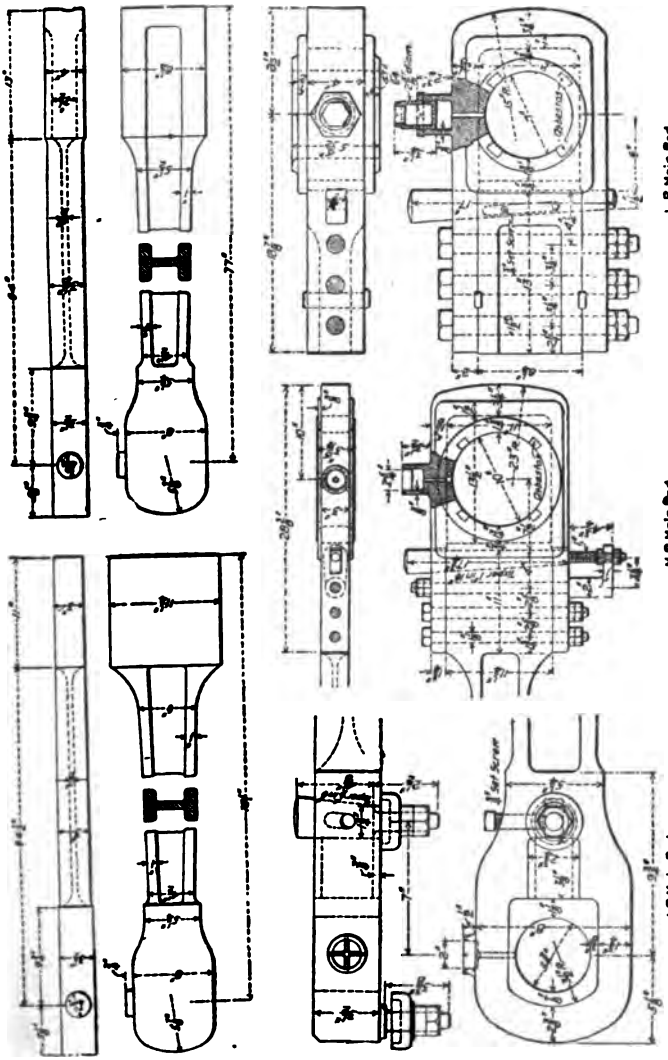


Fig 95 -THESE DRAWINGS ILLUSTRATE THE LIGHTNESS OF THE RODS

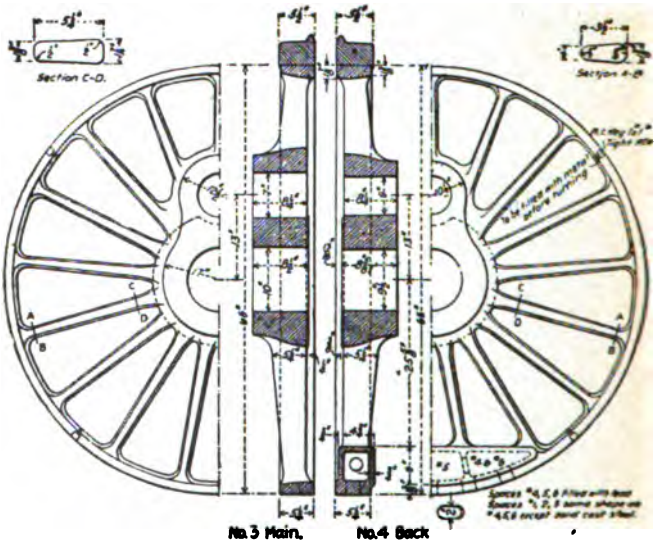
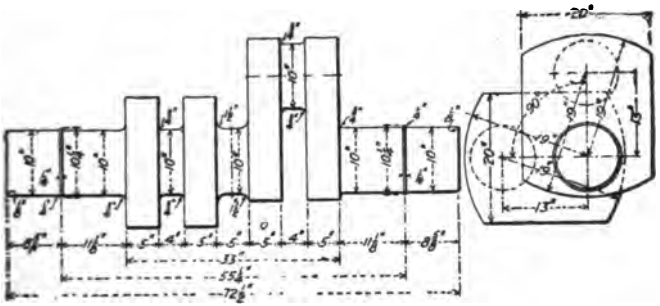


Fig. 98—MAIN AND REAR DRIVING WHEELS



THE CRANK AXLE.

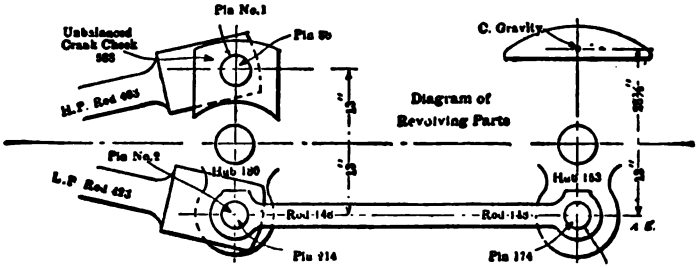
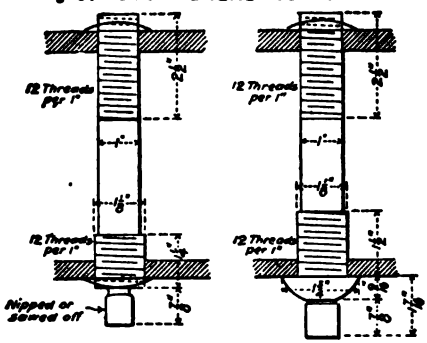


Fig. 97 —COUNTERBALANCING



Style No.1. Fig. 98 Style No.2.

ROWS OTHER THAN CENTER

CENTER ROWS

CROWN STAYS

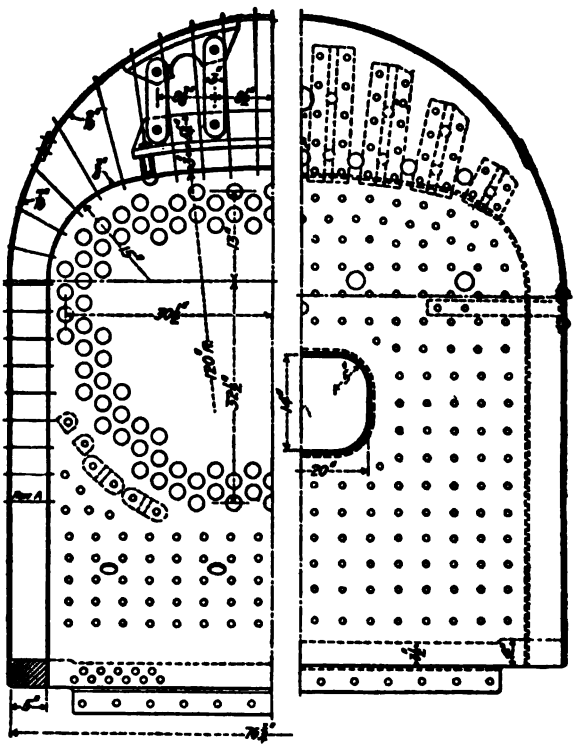


Fig. 99—FIREBOX, SHOWING 6-IN MUD RING

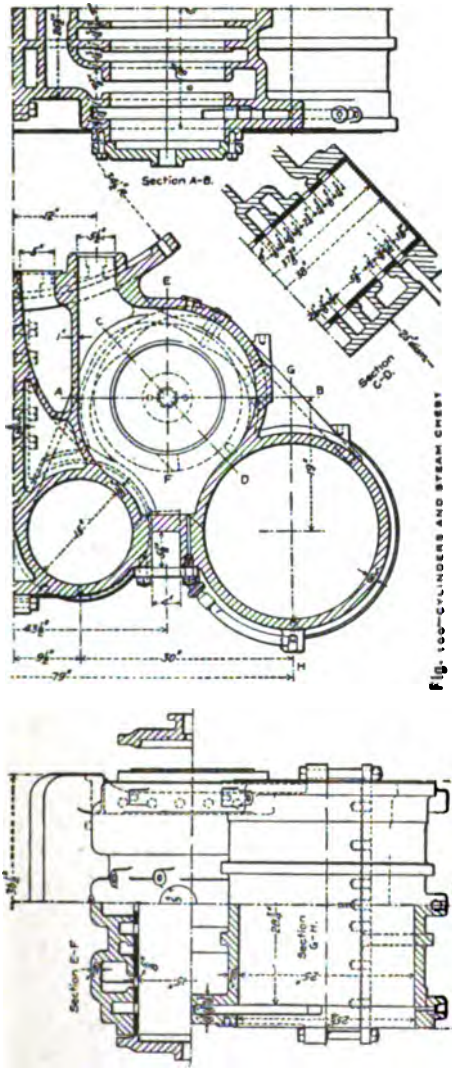


Fig. 100—CYLINDERS AND STEAM CHEST

Another example of the Vauclain 4-Cylinder Balanced Compound is given in the following drawings (Figs. 101 to 105) and tables.*

This locomotive embodies the principles of the former designs but is especially arranged, in the matter of detail, to meet the conditions of the road for which it was built. The following indicate some of the leading differences between the two designs:

	Burlington.	Santa Fe.
Diameter of driving wheels	78 ins.	73 ins.
Weight on drivers	100,000 lbs.	90,000 lbs.
Total weight	192,000 lbs.	187,000 lbs.
Total heating surface	3,216.9 sq. ft.	3,029 sq. ft.
Grate area	44.14 sq. ft.	49.4 sq. ft.
Largest diameter of boiler	64 ins.	66 ins.
Length of tube	19 ft.	18 ft. 1 in.

With the same size cylinders, 15 and 25x26 in. in both engines, the tractive effort of the one is less than that of the other, the tractive effort of the former† being 21,400 lbs., whereas that of the latter‡ is 24,000 lbs., in compound working for both cases. In the design of the locomotive now being described, advantage is taken of the balancing of the reciprocating parts in order to increase the weight on driving wheels, which, in this case, is made 100,000 lbs. This engine has outside journals for the trailing whee The crank axles are forged, and 4½ in. pins are forced in through the crank pin portions. The crank cheeks are banded by tire steel hoops, finished all over, then heated, bent to shape and shrunk on. The following are the ratios and dimensions of the engine:

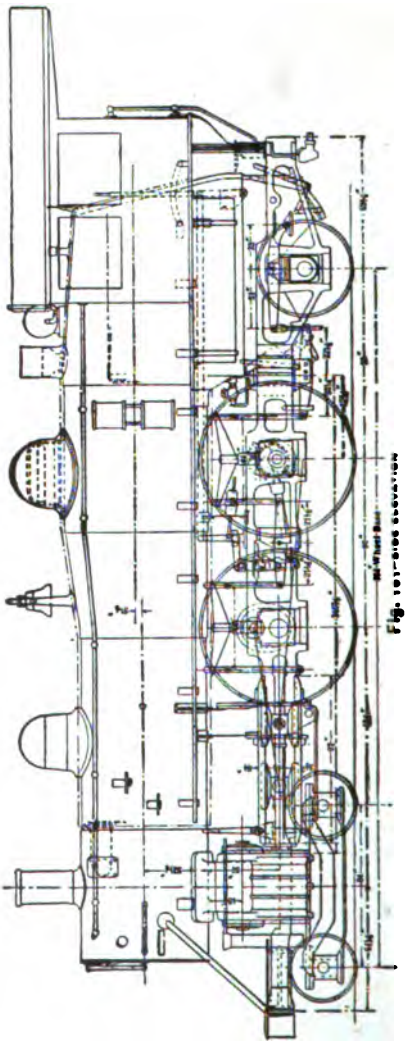
*Built by the Baldwin Locomotive Works for the Chicago, Burlington & Quincy, 1904.

†The A. T. & S. F. engine.

‡The C. B. & Q. engine.

RATIOS AND DIMENSIONS.

Heating surface to volume of high-pressure cylinders, 606.9.
Tractive weight to heating surface, 31.08.
Tractive weight to tractive effort, 4.67.
Tractive effort to heating surface, 6.65.
Heating surface to grate area, 72.88.
Heating surface to tractive effort, 15.03 per cent.
Total weight to heating surface, 59.68.
Tractive effort X diameter of drivers to heating surface, 518.8.
Gauge, 4 feet 8½ inches.
Cylinders, 15 inches and 25 inches x 26 inches.
Valves, balanced piston.
Boiler—Type, wagon top. Diameter, 64 inches.
Thickness of sheets, 11-16 inch and ¾ inch.
Working pressure, 210 pounds.
Fuel, soft coal.
Staying, radial.
Firebox—Material, steel.
Length, 96⅛ inches.
Width, 66¼ inches.
Depth, front, 70⅜ inches; back, 68⅜ inches.
Thickness of sheets, sides, ⅜ inch; back, ⅜ inch; crown, ⅜ inch; tube, ½ inch.
Water space, front, 4 inches; sides, 4 inches; back, 3 inches.
Tubes—Material, iron.
Wire gauge, No. 11.
Number, 274.
Diameter, 2¼ inches.
Length, 19 feet.
Heating Surface—Firebox, 166.4 square feet.
Tubes, 3,050.5 square feet. Total, 3,216.9 square feet.
Grate area, 44.14 square feet.
Driving Wheels—Diameter outside, 78 inches.
Diameter of center, 70 inches.
Journals, front, 10x10½ inches; back, 9½x12 inches.
Engine Truck Wheels (Front)—Diameter, 33 inches.
Journals, 6x10 inches.
Trailing Wheels—Diameter, 48 inches.
Journals, 8x12 inches.
Wheel Base—Driving, 7 feet 3 inches.
Rigid, 15 feet 6 inches. Total engine, 30 feet, 2 inches.
Weight—On driving wheels, 100,000 pounds.
On truck front, 50,000 pounds.
On trailing wheels, 42,000 pounds.
Total engine, 192,000 pounds.
Total engine and tender, 312,000 pounds.
Tank—Capacity, 6,000 gallons.
Tender—Wheels, number 8, diameter 37¼ inches.
Journals, 5x9 inches.
Service, passenger.



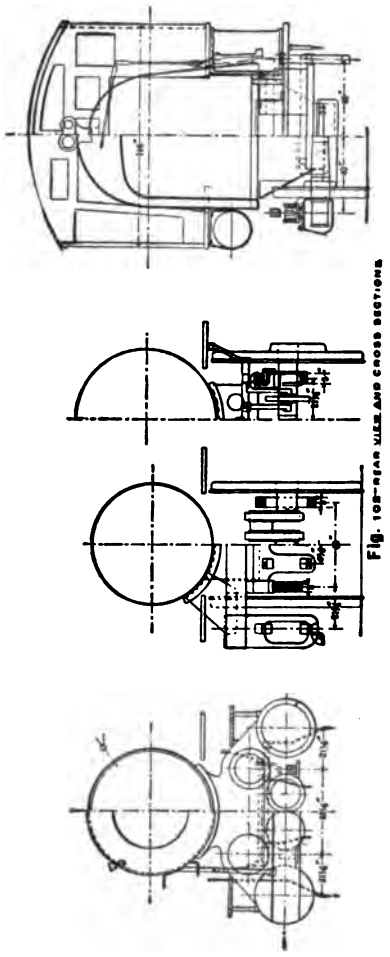


Fig. 105—REAR END AND CROSS SECTIONS

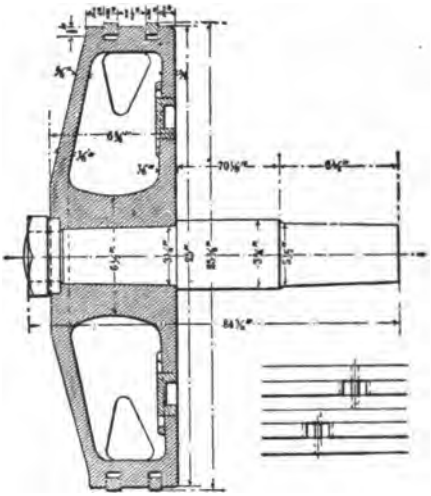


Fig. 103—LOW PRESSURE PISTON

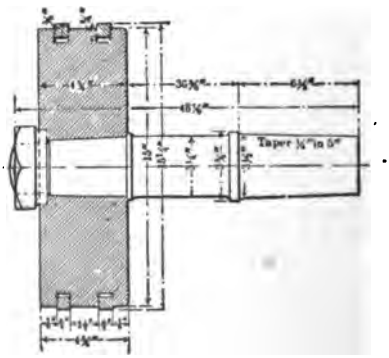


Fig. 104—HIGH PRESSURE PISTON

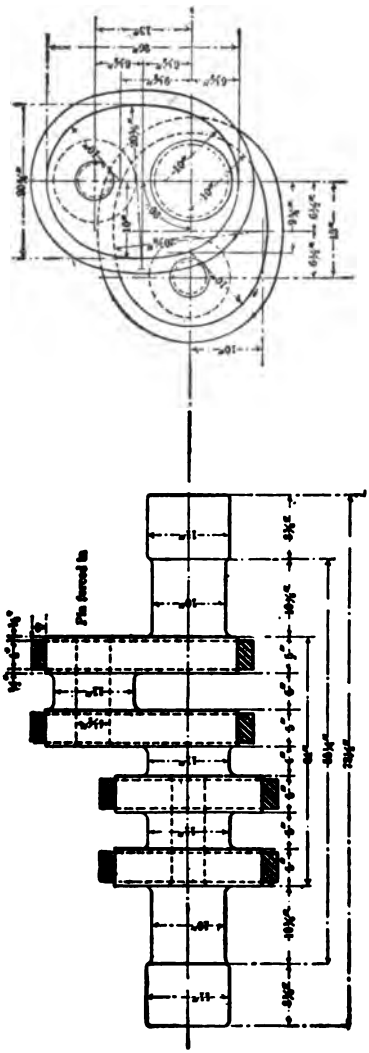


Fig. 106—CRANK AXLE SHOWING SANDING

COLE FOUR-CYLINDER BALANCED COMPOUND.*

In this locomotive, illustrated in drawings Figures 106 to 111, the low pressure cylinders are located in the position common to simple engines, being outside of the frames and attached by a saddle casting to the smoke arch. The high pressure cylinders are situated forward of the saddle casting and between the frames which are extended to such length as to support them. The pistons of the high pressure cylinders are connected to the forward axle, which is suitably cranked to accommodate such connections between the frames. The low pressure cylinders are connected to the rear pair of drivers. By this arrangement of cylinders long connecting rods are possible both inside and outside of the frames.

The cranks on each axle are at 90 degrees to each other and so disposed that the outside crank is at 180 degrees with its adjacent inside crank. The valves are of the piston type and the valves of both the high pressure and low pressure cylinders on one side are connected to the same valve stem and operate within a continuous valve chest which acts as a receiver between the high pressure and low pressure cylinders very much as in the design of Schenectady tandem compound. The valves are operated by the usual Stevenson link motion so that no complications are introduced in this particular. The high pressure cylinders are 15½ inches in diameter by 26-inch stroke and the low pressure cylinders are 26 inches in diameter by the same length of stroke. The engine operates under 220 lbs. of steam and the outside diameter of drivers is 79 in. Applying these fig-

*Designed by F. J. Cole, mechanical engineer for the Schenectady Locomotive Works for the New York Central & Hudson River Railroad, 1904.

ures to the usual formula for four-cylinder compound locomotives proves that this engine is capable of a tractive power of 23,800 lbs.

This engine has been tested in high speed passenger service, hauling a train of 13 cars, and its performance was satisfactory. The general plan shows that the designer has been able to successfully adapt an entirely new arrangement of engines to the usual construction of an American Atlantic type. The crosshead and guide for the high pressure cylinders are located under the saddle of the low pressure cylinder, and it has taken considerable ingenuity to work out the detail. It appears to be a difficult place to get at for repairs and lubrication, but not more so than the valves of the inside connected English engines, and when crank axles and inside cylinders are used the method of repairing must be adaptable thereto.

The principal dimensions are as follows:

Weight in working order, 200,000 pounds.
Weight on drivers, 110,000 pounds.
Weight, engine and tender, in working order, 321,600 pounds.
Wheel Base—Driving, 7 feet.
Rigid, 16 feet 6 inches.
Total, 27 feet 9 inches.
Total, engine and tender, 53 feet 8 inches.

CYLINDERS.

Diameter of cylinders, 15½ and 26 inches.
Stroke of piston, 26 inches.
Diameter of piston rod, 3 inches.

VALVES.

Kind of slide valves, piston type.
Greatest travel of slide valves, 6 inches.
Outside lap of slide valves, 1 inch.
Inside clearance of slide valves, high pressure, ¼ inch; low pressure, ⅜ inch.
Lead of valves in full gear, ¼ inch lead forward motion when cutting off at 11 inches of the stroke.

WHEELS, ETC.

Diameter of driving wheels, outside tire, 79 inches.
Material of driving wheels, centers, cast steel.

Tire held by shrinkage and retaining rings.
Driving box material, cast steel.
Driving journals, 10 inches diameter by 12 inches.
Main crank-pin journals, side, 6¾ inches by 4 inches; back, 6 inches diameter by 6 inches.
Side rod crank-pin journals, front, 5 inches diameter by 3¼ inches.
Engine truck journals, 6½ inches diameter by 12 inches.
Diameter of engine truck wheels, 36 inches.

BOILER.

Style, straight top, radial stay.
Outside diameter of first ring, 72¼ inches.
Working pressure, 220 pounds.
Material of barrel and outside of firebox, steel (Worth Bros.).
Thickness of plates in barrel and outside of firebox, 13-16 inch, 9-16 inch, 5/8 inch.
Firebox—Length, 96⅛ inches.
Width, 75¼ inches.
Depth, front, 80¼ inches; back, 69 inches.
Material, carbon steel.
Plates, thickness, ⅜ inch; tube sheet, ½ inch.
Water space, front, 4 inches and 5 inches; sides, 3½ inches and 5½ inches; back, 3½ and 4½ inches.
Stay bolts, Taylor iron, 1 inch diameter.
Tubes—Material and gauge, Worth, charcoal iron, No. 11, B. W. G.
Number, 390 2-inch.
Length over tube sheets, 16 feet.
Firebrick, supported on water tubes.
Heating Surface—Tubes, 3,248.1 square feet.
Water tubes, 23 square feet.
Firebox, 175 square feet.
Total, 3,446.1 square feet.
Grate surface, 50.3 square feet.
Exhaust nozzles, minimum, 5⅜ inches maximum, 5⅞ inches.
Smokestack—Inside diameter, 18 inches.
Top above rail, 14 feet 8 inches.
Boiler supplied by N. & Co. Monitor No. 11 injector.

TENDER.

Weight, empty, 51,600 pounds.
Wheels, diameter, 36 inches.
Journals, diameter and length, 5½ inches diameter by 10 inches.
Wheel base, 16 feet 9½ inches.
Tender frame, 10-inch channels.
Central bearings, Fox pressed steel frames and bolsters.
Water capacity, 6,000 U. S. gallons.
Coal capacity, 10 tons.
Brake, Westinghouse-American on all drivers and trailers, on tender and for train. Corrington consolidated and engineers' valve and parts.

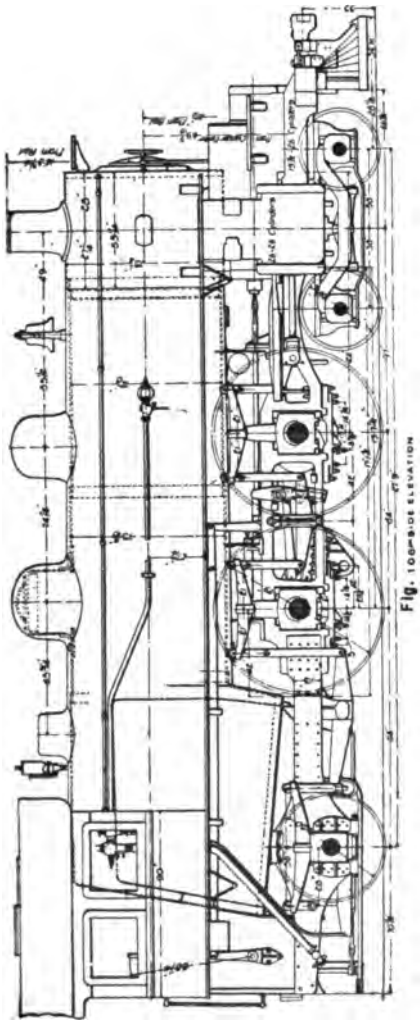


Fig. 100—SIDE ELEVATION

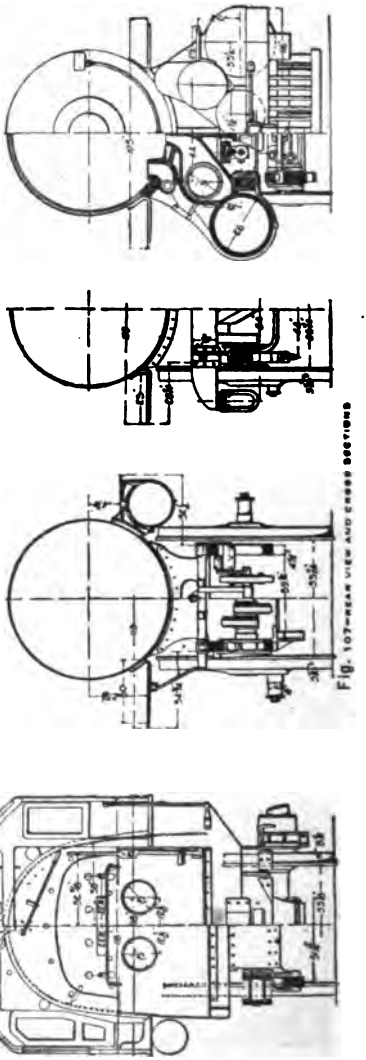


Fig. 107—REAR VIEW AND CROSS SECTIONS

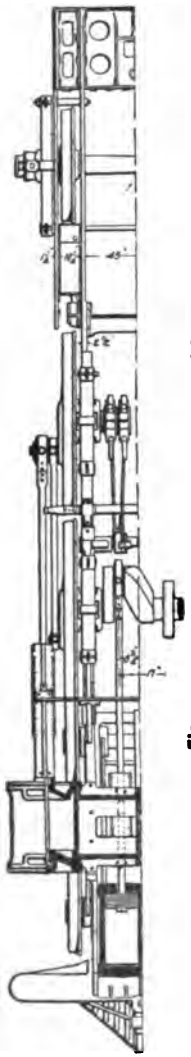


Fig. 100—SIDE PLAN OF RUNNING GEAR AND VALVE MOTION

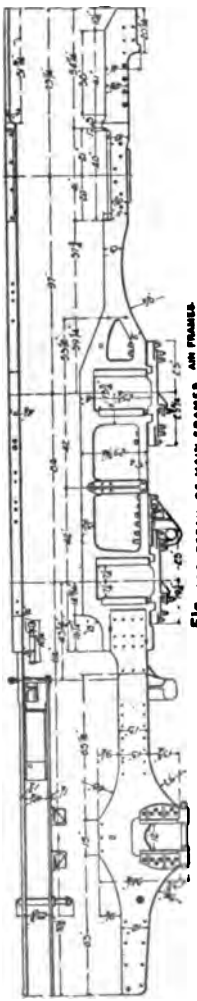


Fig. 101—DETAIL OF MAIN FRAMES AND FRAMES

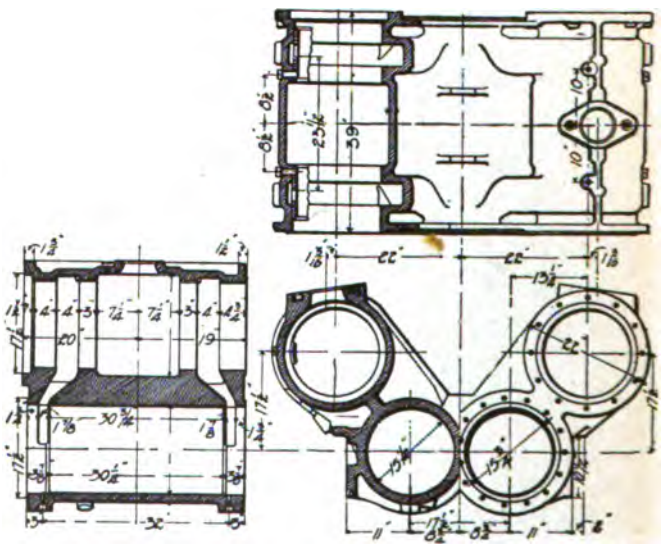


Fig. 110—HIGH PRESSURE CYLINDERS

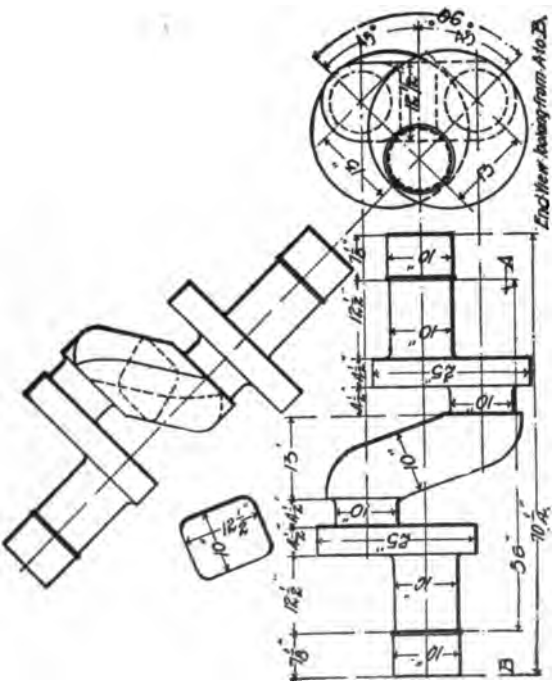


Fig. 111—TEN-INCH CRANK AXLE

DE GLEHN FOUR-CYLINDER BALANCED COMPOUND.*

This engine weighs about 160,000 pounds, with about 83,000 pounds on the driving wheels. Its maximum tractive effort is about 19,800 pounds running compound. Its grate area is 33.9 square feet. In France locomotives of the same type and but little lighter than the imported locomotive referred to have records of handling trains of from 200 to 300 tons at sustained speeds of 60 to 70 miles an hour for distances considerably in excess of 100 miles.

*Built in France for the Pennsylvania Railroad, 1904.

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CHAPTER XII.

PROGRESSIVE EXAMINATIONS FOR FIREMEN—THEIR UTILITY—QUESTIONS AND ANSWERS IN DETAIL.

On all railroads it is the practice to examine applicants for employment as firemen although the scope of such examination differs in varying degree. Some sort of examination manifestly must be made. For instance it is essential that the person seeking service should in every case have certain physical qualifications as to eyesight, hearing and bodily condition, these being fundamental; that he is duly qualified in these respects is ascertainable only by examination.

With the perfecting of the organization of the railway service, the scope of the examination is constantly being enlarged until it has become the general custom to examine the fireman progressively, that is from year to year in order to ascertain that he is mastering his profession and becoming duly qualified for the more responsible and onerous duties of engineer. But aside from this the progressive form of examination has many advantages.*

*Even if a railroad company does not enforce technical examinations such as are referred to, still their study as herein set forth will materially aid firemen and others in acquiring the knowledge they must possess in order to qualify them to run an engine, and will moreover fit them to take service on lines where such examinations are in vogue. The subject, therefore, no matter how it presents itself, is of interest to all firemen.

The young man when first employed as a fireman has his attention called to a number of facts concerning the operation of locomotives that he must be thoroughly conversant with if he is to be successful as a fireman. For this reason the study of the question list during the year preceding his first examination will keep him thinking and studying about these and other facts, that will induce habits of investigation in order to solve the problems he will encounter in his work. This training of the mind followed up by the successive examinations he knows he must encounter will tend to his development and to the mastery of his profession in all its ramifications so that when he takes charge of an engine he is fully equipped mentally and physically to control the machine of which he has been placed in charge and of which he is expected to be the master.

It is the practice upon some roads when a young man is first employed as a fireman to send him out for a number of trips on an engine as a student under the instructions of an experienced fireman so that he may become acquainted with hand, lamp and whistle signals and be sufficiently familiarized with the scoop to be able to keep up steam under ordinary conditions. When he has attained this knowledge and is recommended by the engineer under whose charge he has been at work he is then examined as to his understanding of the signals, etc., and if found proficient is duly enrolled as a fireman. Some roads place the applicant on an engine on probation for a definite period, say six months, with the understanding that continued employment will depend upon his conduct and work. If he does not give satisfac-

tion he is dropped from the service but if satisfactory his employment dates from the beginning of his service.

At the end of a year's service or as soon thereafter as possible, the young fireman undergoes an examination on the lines of the questions, hereinafter set forth, known as the "First Series of Questions." The examination is both written and oral. If his answers are correct, or a certain percentage thereof, he is passed; if he fails in the examination, he is usually afforded another trial with the same series of questions not less than two months and not more than six months from the date of the examination.

When the fireman has passed the "first series" of questions he is supplied with the "second series" and examined thereon at the end of the second year; after passing this second examination he is supplied with the "third series" and if he passes will be qualified for promotion.

The underlying reason for the pains railroad companies take to foster the efficiency of firemen lies in the fact that they are thus building up a corps of competent locomotive engineers. From this point of view it is necessary that the firemen should possess certain fundamental qualifications such as an education of at least a common school grade, good habits and a good physique. Having these attainments to start with advancement will come to those who are conscientious in discharging their duties and who devote some of their leisure hours to study. As an aid to this and in order that the highest efficiency may be attained by the locomotive fireman the questions propounded herein are placed in his hands. The

preparation necessary to correctly answer these questions will require not only study but an intelligent understanding of the many acts that make up his daily work, which together will eventuallv fit him for the responsible duties of an engineer.

It will not, it is needless to say, be sufficient to memorize the answers to questions given herein. They are given simply as a help and guide. Those who conduct the examinations will ask questions in different forms to determine how well the person being examined understands the subject, so that it is necessary that the full meaning of each answer be understood.

The intelligent and conscientious fireman will make use of every avenue by which knowledge can be gained. If there is a school of instruction provided by the company he will avail himself of its advantages, and he is always expected to seek his master mechanic, general foreman, road foreman, traveling engineer, air brake inspector, or any other competent official, for such information as he may require relating to his duties. All this must be further supplemented by close and intelligent observation of the working of the locomotive itself by careful inspection of every breakdown or disabled engine that comes to his notice to observe where and what parts have given way and to note in what manner the blocking, etc., is done.

The questions that follow are arranged generally in the order prescribed by The Traveling Engineers' Association, supplemented by others which seemed necessary to a fuller elucidation of the subject. All the questions are specific and

such as are suggested by the practical experience of those versed in such matters.

It will always happen that conditions on different railroads vary as for instance Compound Engines are not in service on all roads, oil burning locomotives are restricted to those properties where that fuel can be economically used, electric head lights have not been universally adopted, and so on. For this reason the questions and answers on these subjects are given under separate headings but are available in case of need. The author has not sought here, any more than elsewhere, to be original, but rather helpful; to supplement his limited knowledge whenever possible by the wider knowledge and experience of others. The particular form that an examination shall take is not material, if it is effective.

In reference to the answers given to the various questions, it is not expected, as already intimated, that students will restrict themselves either to the scope or verbiage. The answers given, while correct and such as to throw a clear light on the subject are not necessarily exhaustive. It is expected of firemen, as it is of every man connected with railroads, be he high or low, that he will not be satisfied with what he knows, but will strive to keep on acquiring knowledge. It is not sought here to forestall personal research, but to add to the desire to acquire it by careful study and thought.

The fireman who passes an examination is expected to answer the questions correctly or at least a large percentage of them (generally eighty per cent). The information given will help him wonderfully in framing his own answers on ex-

amination, but will be of still greater value in leading him to give each subject exhaustive thought on his own account.

The three series of questions and ans. ers constituting the examinations are generally familiar to engineers. Nevertheless in their respect and grouping they present new features that will prove valuable, interesting and instructive even to them. It is the general rule of companies enforcing technical examinations who employ engineers having previous experience to require such men to pass the same examination as promoted men. So that the exposition of a locomotive engineer's knowledge as set forth in these questions and answers will appeal to the engineer who has been long in the service equally with the novice just entering it, for if he is to maintain his place in the front rank of his profession and be competent to take service at any place, he must be familiar with present day needs and methods and the exacting requirements in regard to the best and most scientific methods prevailing in the operation of locomotives.*

With these explanatory remarks the several examinations will be given in their order denominated as "Series"; thus the First Series relates to the first year's examination, the Second Series to the Second year's and the Third Series to the third year's.

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*I am indebted for the very full and complete answers to the questions hereinafter set forth, to Mr. E. W. Pratt, an operating official, whose long experience in such matters peculiarly qualifies him as an authority.

FIRST SERIES OF QUESTIONS AND ANSWERS.

Question 1.—What are the fireman's duties on arrival at engine house previous to going out on a locomotive?

Answer 1.—On finding out what engine he is marked up for, the fireman should then examine his fire to see that it is clean; he should try the grates, see that he has his shaker bar and that the grates work properly; should look at the flues and crown sheet to make sure that the engine is not leaking, and if it is leaking, should call the engineer's attention to it. He should then see that he has the proper tools on the engine, that is, scoop, shaker-bar, rake, etc.; also that he has the proper flags, fusees, torpedoes and red light. He should also see that he has plenty of coal and a full tank of water. He should then go to work to build up his fire and get it in proper shape for the run, and if time permits should assist the engineer in his work, as is customary. It is hardly necessary to say that any cleaning that is prescribed as part of fireman's duties should be done before engine leaves the roundhouse.

Question 2.—What pressure is indicated by the steam gauge? What is meant by atmospheric pressure?

Answer 2.—The pounds pressure per square inch above atmospheric pressure. The weight or pressure of the atmosphere (or air) which surrounds the earth—about 15 pounds per square inch at sea-level.

Question 3.—What is the source of power in a steam locomotive? What quantity of water ought to be evaporated in a locomotive boiler to the pound of coal?

Answer 3.—Steam, which is generated by heat. From 6 to 10 pounds, depending largely upon the coal and the conditions of combustion.

Question 4.—What is steam, and how is it generated?

Answer 4.—Steam is the vapor of water, generated by heating water above the boiling point.

Question 5.—At what temperature does water boil?

Answer 5.—At 212° Fahr., when subjected to atmospheric pressure only.

Question 6.—What is the temperature of water in a boiler when the pressure is 200 pounds?

Answer 6.—About 388° F.

Question 7.—What is combustion?

Answer 7.—It is the uniting with oxygen of any combustible material. "Burning" is a simple term for combustion.

Question 8.—What is the composition of bituminous coal?

Answer 8.—Bituminous coal of a good quality contains

about 62% of fixed carbon, about 30% of hydro-carbon (volatile matter), about 7% of ash and 1% of sulphur.

Question 9.—What is carbon? From what is oxygen obtained?

Answer 9.—Carbon is an element of Nature. It forms the principal part of all kinds of fuel. Oxygen is obtained from the air.

Question 10.—What per cent. of oxygen is in the atmosphere?

Answer 10.—About one-fifth (or 20.6%) in volume.

Question 11.—Is air necessary for combustion? Why?

Answer 11.—Yes, because one of the elements (oxygen) necessary for combustion is obtained from the air.

Question 12.—About how many cubic feet of air are necessary for the combustion of a pound of coal in a locomotive fire-box?

Answer 12.—For perfect combustion sufficient air must be had to form carbonic acid gas (CO_2), which would be from 200 to 300 cubic feet.

Question 13.—What is the effect upon combustion if too little air is supplied through the fire? If too much air is supplied?

Answer 13.—Incomplete combustion giving off carbon mon-oxide (CO). Too much air absorbs the heat of the fire and if strong enough would "blow it out" as one does a lighted match.

Question 14.—What effect on combustion has the closing and opening of dampers?

Answer 14.—It regulates the amount of air admitted to the grates.

Question 15.—How is a draft created through the fire?

Answer 15.—The draft through the fire is created by the action of the exhaust steam from the cylinders passing through the nozzle in the front end and up through the stack. This exhaust through the stack acts like a piston in driving the air and gases out and leaving a partial vacuum in the front end. In an effort to fill this vacuum the air from the ash pan passes through the grates, fire, and flues.

Question 16.—Describe a blower, its use and abuse.

Answer 16.—The blower consists of a cock on the boiler-head in the cab with a pipe coupled to it leading to and terminating in the smoke box or front-end near the nozzle and pointing upward toward the stack. Its use is to create a forced draft on the fire when the engine is not working. The abuse consists in using it too strongly while the fire-box and grates are being cleaned of ashes and clinkers, or while the fire-box door is open when there is only a light fire, thus drawing cold air through the flues and causing them to con-

tract and leak. The blower should only be used when the steam is shut off to keep the fire burning brightly where necessary to increase the pressure or in maintaining the pressure while the injector is being worked.

Question 17.—What good and bad effect is produced by opening the fire-door when engine is being worked?

Answer 17.—By partially opening the fire-door black smoke and popping can be prevented. Too much opening of the door causes the chilling of the flues and fire-box sheets producing leakage and cracks.

Question 18.—In what condition, therefore, should the fire be, in order that the best results may be obtained?

Answer 18.—The best results will be obtained by carrying a light fire, a level fire, and a bright fire. The fire should be as light as practicable (not too light, however), because a large quantity of air is necessary for the proper burning of the coal, and with a light fire more air will pass through than otherwise. The fire should be level, so that the air will come through the different parts of the fire equally, thus giving a better mixture of the air and fuel and causing better burning. It must be remembered, of course, that the sides and corners must be kept filled up in good shape so that the cold air will not come directly against the fire-box sheets. The fire should be bright. No matter how much fuel and air there may be in the fire-box, they will not unite and burn unless there is a sufficiently high temperature present. An example of this can be seen watching the burning of a match. There is the fuel and air present before the match burns at all. To start the burning the match must be scratched, the friction producing sufficient heat or "temperature" to start the burning of the head. The wood of the match only burns as the flame heats it up, or, in other words, as the igniting or burning temperature is reached.

Question 19.—What effect has the fire upon a scoopful of coal when it is placed in the fire-box?

Answer 19.—When a shovelful of coal is placed in the fire-box the heat of the fire drives off the volatile gases from the coal, leaving the fixed carbon or coke behind, on the grates. These gases that are driven off will combine with the air and burn if the proper temperature is present, but if there is not sufficient temperature present they will pass off unburned. They are colorless if there is sufficient temperature present to burn them, but with an insufficient supply of air they will only partially burn and the part that does not burn will be in the form of soot or fine particles of carbon, which form black smoke. The coke lies on the grates until the air is admitted to burn it.

Question 20.—What is the effect of putting too many scoops of coal on a bright fire? Is this a waste of fuel?

Answer 20.—Adding too much coal to a fire at one time reduces the temperature in the fire-box below the burning point, with the result that combustion is stopped until this fresh fuel has been heated up to the burning point. During this time, however, there has been heat enough in the fire-box to drive off the gases of the coal and the draft has pulled these out through the stack unburned, thereby causing the engine to fall back in steam and also causing the waste of these unburned gases that pass through the stack, which is a waste of fuel.

Question 21.—In what condition should the fire be to consume the gases?

Answer 21.—The fire must be hot enough so that the necessary temperature for the burning of these gases is present, also light enough so that there is enough air present to mix with and burn them.

Question 22.—What is the temperature of the fire when in this condition?

Answer 22.—It must be above 1800 degrees Fahrenheit, and the temperature can be judged by the appearance of the fire, a bright red fire being just about at a temperature of 1800 degrees.

Question 23.—How can the fire be maintained in this condition?

Answer 23.—A fire can be maintained in this condition by having it properly built to start with. By carrying a light, level, and bright fire as explained above, and by firing light and often with coal that is well broken up, spreading the coal well on the bright spots and closing the door between each scoopful and only adding fuel often enough to maintain the necessary pressure.

Question 24.—What is black smoke? Is it combustible?

Answer 24.—Black smoke is the unburned carbon passing off from the fuel, mixed more or less with the exhaust steam from the engine. This carbon can be burned by having the engine in proper condition and firing carefully.

Question 25.—How can black smoke be avoided?

Answer 25.—By careful and systematic firing, by hollow arch brick and by some types of "smoke burners."

Question 26.—Have you made an effort to practice the smokeless method of firing? What results?

Answer 26.—This question must be answered by each man according to his own experience.

Question 27.—Can the firing be done more intelligently if the water level is observed closely? Why?

Answer 27.—Proper firing can only be accomplished by

watching the way the engine is being handled and pumped. If the water level is high approaching a station or the summit of a grade the fire can be burned low before shutting off, so as to prevent the engine popping off, whereas, if the water level is low a bright fire must be kept up while the boiler is being filled. There are many other similar examples to prove that the water level should be closely watched at all times. Many engineers let the fireman pump the engine so that he can regulate the fire to correspond with the amount of water in the boiler.

Question 28.—What advantage is it to the fireman to know the grades of the road and location of stations?

Answer 28.—This is very important, as the engine must be fired according to the work it is called upon to do.

Question 29.—What is the purpose of a safety valve on a locomotive boiler? Why is more than one used?

Answer 29.—A locomotive boiler is built to withstand a certain amount of pressure. In order to insure safety, every boiler is provided with a safety valve of sufficient size to relieve the boiler of any overpressure which may be generated in it. Two or three pops are generally provided so that in case one fails the others will relieve the boiler.

Question 30.—What should be done to prevent waste of steam through the safety valve?

Answer 30.—Close attention paid to the fire, the injectors and the work at hand. A fireman that knows the road will fire carefully and will plan to burn down his fire in approaching stations and other stopping points and the summits of grades, so there will be as little of this waste of steam at the pops as possible.

Question 31.—What is the estimated waste of coal for each minute the safety valve is open?

Answer 31.—About fifteen pounds of coal are wasted every minute the ordinary pop valve is open. This would be equivalent to one scoopful of coal wasted in a minute, due to this cause.

Question 32.—What should be the condition of fire on arriving at a station where stop is to be made?

Answer 32.—The last coal should have been put in far enough from the station so that the gases are burned out from the coal when the steam is shut off. There should be a good bed of fire in the fire-box, however, so that the fire can be built up quickly and the steam pressure maintained when starting away from the station.

Question 33.—How should you build up the fire when at stations, in order to avoid black smoke?

Answer 33.—By adding small quantities of fuel at a time and opening the blower a small amount. If the fresh fuel is

fired along the sides and in the corners of the box instead of spread on the fire, the first few exhausts will spread it and little smoke will be formed. The door may be left slightly open.

Question 34.—What should be the condition of the fire when passing over the summit of a long grade?

Answer 34.—The gases should be sufficiently burned out of the coal so that when the engine is shut off in tipping over the summit of a grade, there will be a good bright bed of fire left and but little smoke produced. In case that there is plenty of water in the boiler the fire should be allowed to burn down sufficiently so that the engine will not blow off while drifting down the hill.

Question 35.—If the injector is to be used after the throttle is shut off, how should the fire be maintained?

Answer 35.—There should be a good bright bed of coke in the fire-box when tipping over the hill, and the fire should be kept bright by adding more coal and the blower opened if necessary until the boiler is filled to the proper level. In this way a uniform pressure can be maintained and there is not the danger of starting the flues to leaking that there would be should the pressure be allowed to vary any great amount while filling the boiler.

Question 36.—What would be the result of starting a heavy train with too thin a fire on the grates?

Answer 36.—The heavy exhausts which accompany the starting of a train will tear the light fire so badly that holes will be formed and a drop of steam pressure will result. If the fire be light and it is necessary to start a heavy train the door should be held open enough to prevent the tearing of the fire, and it is necessary to watch closely to see that the engine does not slip with the door closed.

Question 37.—Where should the coal as a rule be placed in the fire-box?

Answer 37.—The only general rule that can be given is to cover the bright spots with the fresh coal that is added to the fire, as these bright spots show where the fire is nearly burned out and combustion is taking place the most rapidly, and these spots must be covered or they will burn out and leave dead spots in the fire.

Question 38.—When and for what purpose is the use of rake on the fire-bed allowable?

Answer 38.—The firing should be done in such a manner that the use of the rake would not be necessary; however, in case a bank forms in the fire or there is a dead spot or a clinker that needs to be removed, the rake can then be used. In case of a bank in the fire, the crust of this bank should be broken up and spread over the top of the fire. The rake

should not be thrust down through the fire so as to affect the bed of the fire, except in pulling out clinkers or filling up dead spots, as the surest way to form clinkers is to disturb the bed of the fire by using the rake on it and get green coal next to the grates.

Question 39.—Within what limits may steam pressure be allowed to vary, and why?

Answer 39.—It is, of course, expected that the fireman will keep his engine "hot" all of the time when steam is being used; however when the engine is about to drift down a grade or is going to stand in a siding for some time, it is a good policy to let the steam pressure drop back five or ten pounds, so that the engine will not be blowing off all the while that it is drifting down the grade or standing on the side track. In other cases, when running on level track or on easy pulls, it is just as well to keep the pressure down five or ten pounds so as to avoid the waste of steam from the pops; but any greater variation than five or ten pounds in pressure is liable to cause unequal expansion of the boiler and may start the flues leaking, etc. This should be avoided where possible.

Question 40.—Has improper firing any tendency to cause tubes to leak? How?

Answer 40.—It certainly has, as improper firing may mean holes in the fire or may mean dead spots or banks in the fire that will cause sudden changes of the temperature of the fire-box that are almost certain to produce leaky flues. This is especially true with wide fire-box engines, where great pains should be taken to fire carefully in order to avoid this trouble.

Question 41.—What do you consider abuse to a boiler?

Answer 41.—Allowing the steam pressure to drop away back and then blowing the engine up quickly; overpumping the boiler, thereby reducing the steam pressure and then allowing the pressure to rise quickly; improper firing, allowing sudden changes in the fire-box temperature, should all be considered abuse of the boiler.

Question 42.—How would you take care of a boiler with leaky tubes or fire-box?

Answer 42.—If the flues or the fire-box are leaking sufficiently to put out the fire at any point in the fire-box, a good sized bank should be kept at that point so as to keep the cold air away from the leak. The firing should be done as carefully as possible, and in many instances if the firing is done carefully the leakage will take up and entirely stop during the trip. If necessary to clean the fire on such an engine, throw a few sticks of wood upon the arch or next to the flue sheet so as to blaze up and keep the cold air from

the flues. When the engine finishes the run, with dampers closed, let the fire die down entirely in the box before knocking it (covering the stack also helps). Fire up the engine with a good slow wood fire and without the use of the blower. A good wood fire will often stop leaks of flues and fire-box on the road.

Question 43.—What are the advantages of an arch in the locomotive fire-box?

Answer 43.—It induces a more perfect combustion by retaining the gases in the fire-box until they have reached the igniting point. It thus prevents, partially at least, black smoke by giving the fire time to consume the carbon and gases. It also partially heats the cold air before it enters the flues, and otherwise acts as a deflector on the fire.

Question 44.—Why is it very important that coal should be broken so that it will not be larger than an ordinary sized apple, before being put into the fire-box?

Answer 44.—If coal is broken to about the size of an apple before firing it gives better results than when fired in big lumps, because a greater surface is presented to the action of the fire, burning takes place more rapidly, the coal can be spread more evenly over the fire and a better fire can be maintained if the coal is properly broken.

Question 45.—When and why should you wet the coal on the tender?

Answer 45.—There is no benefit, whatever, obtained from wetting the coal before firing, except in the case of the coal being very fine, in which case wetting will hold it together until it has time to strike the fire and become coked, where otherwise if it were fired dry, the sharp exhaust would pull a large percentage of it through the flues and out of the stack unburned. There is no objection, however, to wetting the coal enough to lay the dust.

Question 46.—What are the advantages of a large grate surface?

Answer 46.—The advantages claimed for a large grate surface are that the draft does not need to be so heavy on the fire; the rate of combustion of the coal is less than with the narrow fire-box and greater economy can be obtained in burning the coal or a poorer grade of coal used.

Question 47.—Why are grates made to shake, and when should they be shaken?

Answer 47.—The grates are made so that they can be shaken in order that the fire may be kept clean and the ashes be shaken out into the ash-pan. They should be shaken often enough to keep the fire clean and in good condition.

Question 48.—What is the result of allowing the ash-pan to become filled with clinkers and ashes?

Answer 48.—The fireman should examine his ash-pan frequently and clean it whenever necessary. If the ash-pan get too full it does not allow the proper amount of air to come through the fire and, consequently, the fire does not burn properly. There is also danger of warping or burning the ash-pan and grates if it is allowed to get too full.

Question 49.—What are the duties of a fireman on arrival at the terminal?

Answer 49.—He should see that his fire is left in proper condition, so that it can be cleaned properly. He should see that the tools are put away, so that when the tank is filled with coal these tools will not all be buried up, and attend to any other duties prescribed by the road for which he is working.

SUPPLEMENTARY QUESTIONS AND ANSWERS TO FIRST SERIES.

Question 1.—What parts of a locomotive boiler are surrounded by water?

Answer 1.—The flues and the fire-box are always surrounded by water.

Question 2.—Why is this?

Answer 2.—In order to generate steam rapidly and still not overheat these comparatively thin tubes and sheets. The greater the area of heating surface in the fire-box and flues, the more rapidly can steam be formed.

Question 3.—Name the parts of the fire-box?

Answer 3.—Two side sheets, a crown sheet, a flue sheet, and a back sheet, in which the door or doors are located.

Question 4.—What will happen if mud gets baked hard on top of a crown sheet?

Answer 4.—The sheet will become red hot and bag down in the spots where the mud is the thickest. This is called a "mud burnt" sheet and must be attended to in order to avoid disaster.

Question 5.—What is meant by the "leg" of a boiler?

Answer 5.—The narrow space between the inside and the outside fire-box sheets.

Question 6.—If scale and mud be allowed to accumulate in a solid mass between the flues, what would happen?

Answer 6.—The flues would become overheated and either burst or collapse. In the one case the water from the burst flue would probably extinguish the fire and kill the engine, while there would be loss of just so much heating surface due to a collapsed flue.

Question 7.—What are the two most important features in assuring the safety and efficiency of a locomotive boiler?

Answer 7.—The inspection and renewal of broken stay-bolts and the frequent and thorough washing out of the boiler with water at a high pressure.

Question 8.—What water pressure is most efficient and what parts of the boiler should be washed most thoroughly?

Answer 8.—About 150 pounds at the nozzle. The crown sheet, the legs of the boiler, over the door or doors, and center flues, especially near the boiler checks where mud is most frequent.

Question 9.—How far should a boiler be run between washouts?

Answer 9.—From 600 to 2,000 miles, depending upon the conditions of the water.

Question 10.—Name the most important rule that should always be observed for the safety of men around a locomotive.

Answer 10.—Always ring the bell before moving, to give anyone an opportunity to get out of harm's way.

Question 11.—Why are the terms "engineman" and fireman used instead of "engineer" and fireman by some roads?

Answer 11.—Because the Rules and Regulations of the American Railway Association, now employed as a standard by most railroads, use the former terms.

Question 12.—Why are both injectors now sometimes placed on the engineer's side of the locomotive?

Answer 12.—Because the fireman's duties on the largest engines are so arduous that it is thought that the engineer should attend to all the boiler feeding.

Question 13.—What parts of the boiler are tne most sensitive to cold air?

Answer 13.—The flues and flue sheets.

Question 14.—If some parts of the grates are bare, how can fire be started there the most quickly?

Answer 14.—Take the ash-hoe or clinker-bar and push some live coals over these bare spots and then cover with green coal.

Question 15.—What is the greatest single expense of a railroad company?

Answer 15.—The fuel for its locomotives.

Question 16.—Who then is in a position to make the most saving?

Answer 16.—The fireman.

Question 17.—Why is a knowledge of the laws of combustion of value to a fireman?

Answer 17.—Because he can save both fuel and labor if he puts these laws into practice.

Question 18.—If coal (or any other form of fuel, such as

wood or oil) burns at all, does it not always give off the same amount of heat?

Answer 18.—No, sir. Perfect combustion gives off three times the heat with the same amount of fuel as does imperfect combustion.

Question 19.—What is the chief cause of imperfect combustion?

Answer 19.—Not enough air being admitted through the fire due to too heavy firing, or the accumulation of ashes and clinkers on the grates.

Question 20.—In what parts of the fire-box is the draft the greatest and where should the most coal be placed?

Answer 20.—In the corners and along the side sheets.

Question 21.—In putting in a fire when should the fireman take a good look in the fire-box for bright spots needing more coal?

Answer 21.—Before putting in the first shovelful, as that should be placed back near the door so that the flame from it will tend to heat the air drawn in with the next shovelfuls.

Question 22.—How much heat will one pound of carbon give off as a result of perfect combustion?

Answer 22.—Nearly 15,000 heat units.

Question 23.—What is a heat unit?

Answer 23.—The amount of heat required to raise one pound of water one degree in temperature.

Question 24.—How many pounds of water will 15,000 heat units cause to be evaporated into steam?

Answer 24.—About 15 pounds.

Question 25.—With imperfect combustion how much heat will one pound of carbon produce? How many pounds of water would this heat convert into steam?

Answer 25.—About 4,500 heat units. About 5 pounds of water.

Question 26.—Can you explain the difference between perfect and imperfect combustion?

Answer 26.—To obtain perfect combustion each particle of carbon must unite with two particles of oxygen, forming the mixture carbonic acid gas (formula:—$C+2O=CO_2$, producing nearly 15,000 heat units). Should the supply of air be too small for obtaining two parts of oxygen for every particle of carbon, one part of each would combine, producing carbonic oxide gas. (Formula:—$C+O=CO$, producing only about 4,500 heat units).

Question 27.—Does this comparison between complete and partial combustion of carbon hold good with regard to soft coal?

Answer 27.—Yes, but to a greater degree, due to the fact that soft or bituminous coal generally contains a large per-

centage (nearly 40) of hydro-carbons and volatile gases; which, if not properly consumed, produce a yet greater loss.

Question 28.—What must be done to burn these hydro-carbons and gases?

Answer 28.—Besides admitting sufficient air, this air must be heated to a temperature high enough to produce combustion, which temperature is about 1,800 degrees.

Question 29.—Then what are the two principal sources of heat in burning soft coal?

Answer 29.—the burning of volatile gases, which gives the flame, and the burning of the fixed carbon, which burns with an intense white heat, like coke.

Question 30.—Then how can the heat from the latter be utilized to burn the volatile gases?

Answer 30.—By only covering a small portion of the grate area at a time, leaving different parts of the fire at a white heat all the time.

Question 31.—Do you consider it necessary to your success in the railroad operating business, where many lives and much property are dependent upon you for their safety, to abstain from the use of all intoxicating liquors?

Answer 31.—I do, and I believe that the associations of saloons and such places are bad and my time can be better spent elsewhere.

Question 32.—Do you consider it for your welfare to work to the best of your ability for the best interests of your employer and be economical in the use of fuel and supplies?

Answer 32.—I certainly do.

Question 33.—Is it your duty to have your watch inspected regularly, compare time daily, and should you insist on reading all train orders?

Answer 33.—If those are the rules of the road for which I am working, I should.

Question 34.—In addition to the various signals given by the operating rules, what else do you consider a danger signal?

Answer 34.—A fire burning on the track, or any violent signals given by any one standing on or near the track. In case of doubt, always adopt the safe course, which would be to stop in such instances.

Question 35.—Explain the principle of the steam gauge.

Answer 35.—There are several kinds of steam gauges, but all of them are operated on either of two principles:—When internal pressure is applied to a bent flat tube, the tendency of the tube is to straighten out in proportion to the pressure. This tendency is utilized in the Bourdon gauge, in which the mechanism necessary for operating the dial pointer is connected with the tube. The other form of gauge

is operated by a double diaphragm of corrugated plates. When pressure is admitted between the plates, it forces them outward in proportion to such pressure, and the attachments operate the gauge pointer.

AIR BRAKE QUESTIONS AND ANSWERS.—FIRST SERIES.*

Question 1.—What is an air brake?

Answer 1.—It is a brake applied by compressed air.

Question 2.—How is the air compressed for use in the brake system?

Answer 2.—By the air pump on the locomotive.

Question 3.—What are the essential parts of the air brake as applied to a locomotive?

Answer 3.—The air pump, the main reservoir, the engineer's brake valve, the train pipe with its hose and couplings, the auxiliary reservoir, the triple valve, brake cylinder, the gauge and pump governor.

Question 4.—How many kinds of triple valves are there in use?

Answer 4.—Two, the plain triple and the quick-action triple.

Question 5.—What is the main reservoir used for and where it is located?

Answer 5.—The main reservoir is for storing air in advance of its need for any purpose. Its air is principally used to restore pressure to the train line; also for signal line, bell ringer, air sander, blow off cock, door-opener, water scoop, etc. The main drum is usually located on the engine, but sometimes on the tender.

Question 6.—What is the usual standard train pipe pressure?

Answer 6.—Seventy (70) pounds per square inch.

Question 7.—What pressure is usually carried in the main reservoir?

Answer 7.—Ninety (90) to 110 pounds.

Question 8.—Why is it important that all air brake apparatus should be kept tight and free from leaks?

Answer 8.—Primarily so that its use for the purposes intended will be definite, also to avoid overtaxing the pump.

Question 9.—Where does the air come from that operates the sand blower, bell ringer, blow-off cock, air whistle signal, water scoop and other devices?

Answer 9.—From the main reservoir.

*The Air Brake is fully described and illustrated in another volume of The Science of Railways devoted to the subject.

Question 10.—How should an air pump be started?

Answer 10.—It should be started slowly, allowing the condensation to be drained off and worked slowly until about twenty pounds of air is obtained which will act as a cushion for pump, then open it up and pump up the required pressure. The lubricator should be opened as soon as pump is started, giving pump five or six drops at once, then cut it down to where it should be fed.

Question 11.—How is the automatic brake applied and released?

Answer 11.—It is applied by reducing the pressure in the train line; it is released by increasing the pressure in the train line.

Question 12.—(a) How many positions are there of the brake valve? (b) What are they?

Answer 12.—(a) Five. (b) Release, running position, lap position ,service position and emergency position.

SUPPLEMENTARY QUESTIONS AND ANSWERS, AIR BRAKE.—FIRST SERIES.

Question 1.—Which is the steam and which the air cylinder to the air pump?

Answer 1.—The upper is the steam, the lower the air cylinder in a Westinghouse pump. Just the opposite in a New York pump.

Question 2.—When should the water drip cocks of a pump be opened and when closed?

Answer 2.—Opened when the pump is shut off and done with for the trip, and closed after the pump has been started and all water of condensation worked out.

Question 3.—If a pump nearly stops on a stormy winter day, where would you first look for the trouble?

Answer 3.—The air strainer frozen over with snow and sleet.

Question 4.—What does the black pointer on the air gauge indicate? What the red pointer?

Answer 4.—Train line pressure. Main reservoir pressure.

Question 5.—Should you allow an air pump to run over the ash pit?

Answer 5.—No, because it draws dirt and cinders into the air cylinder.

SECOND SERIES OF QUESTIONS AND ANSWERS.

Question 1.—What, in your opinion, is the best way to fire a locomotive?

Answer 1.—To fire as lightly as consistent with the work required, to avoid smoke trailing back over the train, to avoid popping and to endeavor to maintain a uniform steam pressure under all circumstances.

Question 2.—What is the cause of the drumming noise when engine is shut off? Can and should it be avoided? Why?

Answer 2.—It is said to be a succession of minute explosions of gases in the fire-box; it can and should be avoided by dropping the dampers or opening the door, because the noise is extremely disagreeable to those within hearing.

Question 3.—Describe the general form of a locomotive boiler.

Answer 3.—It is cylindrical in form. It has usually a rectangular shaped fire-box at one end and a smoke-box at the other end. Flues run through the cylindrical part, which, like the fire-box, are surrounded by water.

Question 4.—How does the wide fire-box type of boilers differ from the ordinary boiler and what are the advantages?

Answer 4.—The ordinary (deep) fire-box is limited in width to the distance between the frames; the "shallow" fire-box sets on top of the frames, but between the drivers; the wide fire-box is not only above the frame but extends out on each side beyond the driving wheels. The supposed advantage is to obtain a larger grate area in the same length fire-box so as to cause slower combustion per square foot of grate surface.

Question 5.—Why have two fire-box doors been placed in the large type of locomotive boilers?

Answer 5.—On account of their great width, so that coal can be easily distributed to all parts of the grates.

Question 6.—Describe a locomotive fire-box?

Answer 6.—The modern form is a rectangular shaped structure located at the back end of the boiler. It has a door and is composed of side-sheets, a crown-sheet, a back-sheet and a flue-sheet from which the flues run to the smoke-box located in the front end of the engine.

Question 7.—To what strains is a fire-box subjected?

Answer 7.—To crushing strains and those of unequal expansion and contraction.

Question 8.—How are the sheets of a fire-box supported?

Answer 8.—They are supported by means of stay-bolts

screwed through the inside and outside sheets and with their ends riveted over.

Question 9.—In what manner is a crown-sheet supported?

Answer 9.—By means of crown bars or radial stay-bolts.

Question 10.—What are the bad features about crown-bars?

Answer 10.—They are hard to keep clean, and cause "mud-burnt" crown-sheets.

Question 11.—What are the advantages of radial stayed crown-sheets?

Answer 11.—They are comparatively easy to keep clean and cheaper to repair.

Question 12.—How are the inside and outside sheets of fire-box secured at the bottom?

Answer 12.—They are riveted to a wrought iron ring called the mud-ring.

Question 13.—Describe the ash-pan and its use.

Answer 13.—It is a receptacle secured to the bottom of the fire-box and is provided with two or more dampers designed to regulate the admission of air to the fire. It collects the ashes dropped from the fire-box and thus prevents their setting fire to bridges, cattle-guards, and other property elsewhere along the road.

Question 14.—What is a "wagon-top" boiler?

Answer 14.—It is a boiler which has the fire-box end made larger than the cylindrical part in order to provide more steam space.

Question 15.—Why are boilers provided with steam domes?

Answer 15.—In order to furnish more steam space, obtain dryer steam, and provide a place for the steam pipe, throttle-valve, safety-valves and whistle.

Question 16.—What must be the condition of a boiler in order to give the best results?

Answer 16.—It must have a good circulation and be clean and free from incrustation of any nature, such as scale, mud, etc.

Question 17.—What is meant by "circulation" in a boiler?

Answer 17.—The free movement of the water, so that it may come in contact with the heating surfaces, and after being converted into steam, be immediately replaced by fresh supplies of water.

Question 18.—What would be the effect if a "leg" of the fire-box became filled with mud?

Answer 18.—There would be no water in contact with the heated sheets and they would in consequence quickly become blistered or "mud-burnt." (The narrow water space between the inside and outside sheets of the fire-box is termed the "leg" of a boiler.)

Question 19.—What would be the result if the fire-box sheets became overheated?

Answer 19.—They would be forced off the stay-bolts and an explosion would occur.

Question 20.—Would it be advisable to put water onto a sheet that has become bare and red hot?

Answer 20.—It would not.

Question 21.—What effect has the stoppage of a large number of flues?

Answer 21.—The heating surface and draught are decreased by just so much area.

Question 22.—Why are boiler checks placed so far away from fire-box?

Answer 22.—In order to introduce the water into the boiler at as great a distance from the fire as possible. This permits the water to become somewhat heated before coming in contact with the fire-box and also tends to better circulation.

Question 23.—What part of a locomotive boiler has the greatest pressure? Why?

Answer 23.—The bottom, because to the steam pressure is added the weight of the water.

Question 24.—What is the advantage of the extension front end?

Answer 24.—To provide suitable draft and spark appliances.

Question 25.—What is the object of hollow stay-bolts?

Answer 25.—To immediately indicate by the escape of steam through this small (detector) hole that the stay-bolt is broken.

Question 26.—What will cause an engine to tear holes in her fire?

Answer 26.—Working hard or slipping with dampers open, door closed and too thin a fire.

Question 27.—Name the various adjustable appliances in front end, by which the fire is regulated.

Answer 27.—The exhaust nozzle, the diaphragm and the draft pipes or "petticoat" pipes.

Question 28.—Explain what adjustments can be made, and the effect of each adjustment on the fire.

Answer 28.—Larger or smaller nozzle tips cause less or greater draft on the fire; the angle and position of the diaphram does the same and raising or lowering it burns the fire more at the rear or front end of the fire box. The size and position of the petticoat pipes increases or decreases the draft through the top or bottom flues. These latter adjustments should always be attempted before bushing the nozzle.

Question 29.—What does it indicate when the exhaust issues strongest from one side of stack?

Answer 29.—The exhaust pipe or the petticoat pipes are out of plumb.

Question 30.—What is the effect of leaky steam-pipe joints inside of smoke-box?

Answer 30.—Engine will not steam freely.

Question 31.—What causes "pull" on fire-box door?

Answer 31.—The partial vacuum in the front end; excessive "pull" indicates dampers closed, grates clinkered or stopped up.

Question 32.—If, upon opening fire-box door, you discovered there what is commonly call a red fire, what might be the cause?

Answer 32.—That the grates had become clogged with ashes and clinkers so that sufficient air could not pass through them to the fire.

Question 33.—Is it not a waste of fuel to open fire-box door, to prevent pops from opening? How can this be prevented more economically?

Answer 33.—Yes, sometimes. By putting the heater on the tank or starting the injector.

Question 34.—Describe the principle upon which the injectors work.

Answer 34.—The action of the injector is due, first, to the difference between "Kinetic" or moving energy and "Static" or standing energy; second, to the fact that steam at a pressure travels at a tremendous velocity, and if placed in contact with a stream of water, imparts to the latter much of its velocity and besides is condensed to water itself.

Question 35.—What is the difference between a lifting and non-lifting injector?

Answer 35.—A lifting injector will create sufficient vacuum to raise the water from the level of the tank. The tubes in a non-lifting injector are shaped differently and will not draw the water, but merely force it into the boiler.

Question 36.—Will injector work with a leak between injector and tank? Why? Will it prime?

Answer 36.—Not if a bad leak, it will not prime, because the air admitted through the leak destroys the vacuum necessary to raise the water to the injector level. A non-lifting injector will often work as the water will escape from the leak instead of air into it.

Question 37.—If it primes well, but breaks when steam is turned on wide, where would you look for the trouble?

Answer 37.—Insufficient water supply, due to tank valve not open, strainer stopped up, hose kinked, etc. Injector

tubes out of line, limed up or combining nozzle cut out, wet steam from throttle.

Question 38.—If it will not prime, where would you expect to find the trouble?

Answer 38.—Insufficient water supply (see answer 36) or priming valve out of order.

Question 39.—Will injector prime if checks leak badly or are stuck up? If injector throttle leaks badly?

Answer 39.—Not if either leak badly.

Question 40.—If steam or water shows at overflow pipe when injector is not working, how do you tell whether leak is from check or injector throttle?

Answer 40.—Close the main steam valve on the fountain, which will stop the leak if it be from the throttle.

Question 41.—Will injector prime if primer valves leak? Will it prevent its working?

Answer 41.—No, but may waste some from the overflow.

Question 42.—Will an injector work if air cannot get into tank as fast as the water is taken out?

Answer 42.—It will not.

Question 43.—Will an injector work if all of the steam is not condensed by the water?

Answer 43.—No.

Question 44.—If you had to take down tank hose, how would you stop the water from flowing out of tank that has the syphon connection, instead of the old style tank valves?

Answer 44.—First open the small pet cock at the top of the syphon.

Question 45.—Is the water-glass safe to run by, if the water line in the glass is not moving up and down when engine is in motion?

Answer 45.—It most certainly is not safe.

Question 46.—Is any more water used when an engine foams than when the water is solid?

Answer 46.—Very much more—one cubic inch of water is equal in weight to one cubic foot of steam.

Question 47.—Describe the manner in which a sight feed lubricator operates.

Answer 47.—The steam is condensed into water and flows into the reservoir, as water is heavier than oil. The oil rises and then passes through a tube down into a cavity in the bottom of the lubricator, and then through the sight feed glasses, which are filled with water. There it is caught by a jet of steam from the equalizing tube and is taken into the oil pipe leading to the cylinder.

Question 48.—Does the draught from an open cab window affect the working of the lubricator? Why?

Answer 48.—Yes, the cold air chills the oil which will not flow regularly unless it is of uniform temperature.

Question 49.—What else might cause irregularity of feed?

Answer 49.—Dirt in the lubricator or choke plugs too large.

Question 50.—If a lubricator feeds faster when throttle is closed than open, where is the trouble?

Answer 50.—Choke plugs too large in opening.

Question 51.—Will any bad results ensue from filling a lubricator full with cold oil?

Answer 51.—Yes, when the oil becomes hot it will expand and may bulge or burst the lubricator.

Question 52.—If the sight feeds get stopped up, how would you clean them out?

Answer 52.—Remove the regulator valves and blow out the nozzle with steam; or run a fine wire or pin through the holes.

Question 53.—How would you clean out chokers?

Answer 53.—By disconnecting the oil pipes and running a wire through them.

Question 54.—Which is the better practice, to close feed valves or water valves, while waiting on sidings, etc.?

Answer 54.—The feed valve, as the water valve may not be tight.

Question 55.—How can you tell if equalizing tubes become stopped up or broken?

Answer 55.—The oil would spurt in a stream through the glass with tubes stopped up; if broken off no oil could flow through the feed and you would have to use the auxiliary oiler.

SUPPLEMENTARY QUESTIONS AND ANSWERS TO SECOND SERIES.

Question 1.—What causes a tank to sweat?

Answer 1.—The water in the tank being colder than the atmosphere.

Question 2.—Is sweating injurious to the paint and varnish and how can it be avoided?

Answer 2.—Very much so, and it can be avoided by putting the heater on the tank so as to bring the water to the temperature of the air.

Question 3.—Have you made an effort to practice economical firing during your past year, and what success have you obtained?

Answer 3.—This should be carefully answered according to facts.

Question 4.—What is a hollow arch? What are its advantages and how can it be kept effective?

Answer 4.—It is an arch constructed with air passages which are connected with the atmosphere by tubes passing through the fire-box sheets. It deflects air over the fire, more thoroughly mixing the oxygen with the gases and thus aids combustion. To preserve these advantages the tubes must be kept open.

Question 5.—How is the greatest injury done to a boiler when cleaning or knocking the fire?

Answer 5.—By putting the blower on hard and drawing cold air through the fire-box and flues.

Question 6.—What good practice is sometimes followed to keep cold air from the flues and fire-box after the fire has been knocked out?

Answer 6.—Some roads have smoke jacks in their round-houses with tight dampers that may be closed; others put a cover over the top of the locomotive stack to stop the draft. In all cases the ash pan dampers and fire-door should be closed.

Question 7.—After the steam heat throttle is opened, how can you regulate the reducing valve to the required pressure for the train heating?

Answer 7.—By increasing or decreasing the tension of the spring on top of the diaphragm of the reducing valve.

Question 8.—In winter, when the steam heat is not in use, what should be done?

Answer 8.—The steam heat throttle should be opened sufficiently to cause a circulation of steam through the pipes on the engine and tender so as to prevent their freezing.

Question 9.—How would you prevent injectors, feed pipes, etc., from freezing up in winter when not in use?

Answer 9.—The steam valve should be slightly opened to cause a circulation of steam through the feed and branch pipes and the pet cock opened to permit circulation through the latter pipe. With lifting injectors, first close the heater cock.

Question 10.—How do most railroads base their comparative coal records.

Answer 10.—On the ton-mileage basis, that is, the number of rounds of coal burned per 100-ton-miles.

Question 11.—Then with what kind of a train will you make the best record?

Answer 11.—With the heaviest train up to the economical loading of the engine.

Question 12.—Give examples of the record with a light and with a heavy train in this respect.

Answer 12.—First, suppose I went over a 100-mile division with a train only weighing 200 tons and burned 3 tons of coal, $200 \times 100 = 20{,}000$ ton-miles or 200 hundred ton-miles;

3 tons coal equals 6,000 pounds. 6,000 divided by 2,000 equals 30 pounds of coal burned per 100-ton-miles. Second, suppose I made the same trip with a train weighing 1,500 tons and burned 7½ tons of coal. 1,500×100 (miles) equals 150,000 ton-miles or 1,500 hundred-ton-miles. 7½ tons coal equals 15,000 pounds. 15,000 divided by 1,500 equals 10 pounds of coal per 100 ton-miles, which is three times as good as the former case.

Question 13.—Why does putting a large quantity of cold water into a boiler cause flues to leak? When is this most serious?

Answer 13.—The flues contract in length as well as diameter, and it has a tendency to pull them out of the flue-sheet, thus loosening them. After the fire has been knocked this tendency is much greater; hence cold water should never be put into a hot boiler after the fire is drawn—fill the boiler before knocking the fire.

Question 14.—Name one thing that will cause the grates to clinker badly.

Answer 14.—Frequent and hard use of the blower.

Question 15.—How should the cab lamps, the signal lamps, oil cans and lanterns be cared for?

Answer 15.—They should all be kept clean, free from leaks and filled before starting any trip.

Question 16.—Are the signal lamps important?

Answer 16.—The safety of trains often depends upon the proper burning of the signal lamps.

Question 17.—What should be done in case of a sudden and unexpected stopping of the train and the consequent liability of the engine blowing off?

Answer 17.—Blow steam back into the tank, but not strong enough to blow off the tank hose, and heat the tank water up to the temperature of your hand.

Question 18.—Is warm water in the tank of considerable advantage in making steam rapidly?

Answer 18.—It is; in the same way that a boiler full of hot water is a greater reservoir of stored heat. Careful experiments have shown that a locomotive boiler will generate one per cent. more steam for every 11 degrees that the tank water is heated. Thus heating the water in the tank from 50 to 94 degrees would effect a saving of 4 per cent.

Question 19.—Then why not heat the tank water up to 212 degrees, the boiling point?

Answer 19.—First, because it would ruin the paint and varnish on the tank; and second, because if the water is heated much above blood heat (about 100°) it will not condense enough steam in the injectors to cause them to work properly. Some injectors will take hotter water than others.

Question 20.—With a light fire if the engine should slip, how can damage to the fire be prevented?

Answer 20.—By quickly opening the fire-box door, thus permitting the air to be drawn over the fire for the instant, instead of through it.

Question 21.—What is the principle of the so-called "re-starting" injectors?

Answer 21.—They have large overflow openings and, should the injector break, the air and steam will blow out of the overflow, thus maintaining sufficient vacuum in the feed pipe to again draw the water to the injector.

Question 22.—At 200 pounds pressure per square inch, what is the pressure per square foot on the sheets of a boiler?

Answer 22.—About 15 tons.

Question 23.—What is the total pressure on the fire-box of a large locomotive?

Answer 23.—Over 3,000 tons.

Question 24.—Should an engine ever be slipped to get water out of the steam passages?

Answer 24.—Never. Open the cylinder cocks and start the engine slowly.

Question 25.—Who is the captain of a locomotive, and should his wishes be complied with?

Answer 25.—The engineer; and the fireman should endeavor to do his work in a manner pleasing to the engineer.

Question 26.—Should the gangway and deck be kept clear of coal and in warm weather the coal wet down?

Answer 26.—Yes; coal falling from an engine endangers the lives of section men or others Always keep down the dust in the cab as much as possible.

Question 27.—Should a fireman anticipate the work his engine is about to do?

Answer 27.—Yes; therein lies the greatest success for any fireman; for it should be remembered that to give the greatest heat, a fire should be put in and gotten well to burning before the hard work for the engine comes or the injector is put to work.

Question 28.—What does it indicate when smoke trails back into the passenger cars, after shutting off?

Answer 28.—Either a poor fireman or else a lack of understanding between the engineer and fireman as to where the engine was to be shut off.

Question 29.—Before shaking grates or dumping ash-pans, what should you notice?

Answer 29.—That you are not passing over bridges, cattle-guards, etc., that might be set a-fire.

Question 30.—Which is the easier and more satisfactory

in the long run, to stop and clean a dirty fire or continue without so doing to the end of a long, hard trip?

Answer 30.—Stop and clean the fire and thus save fuel and labor for the remainder of the trip. Many a time you will also save an engine failure by so doing.

Question 31.—Should you examine the flues to see if they are stopped up and inspect grates and grate rigging carefully before leaving your engine at terminals?

Answer 31.—Yes, so that they can be reported if necessary. Clean flues and grates working well, make a vast difference in the success of a fireman and there is one thing more than any other to appreciate, namely, that successful work—no matter how arduous—is always much easier and less disheartening than unsuccessful work.

AIR BRAKE QUESTIONS. SECOND SERIES.

Question 1.—Can you tell by the length of the exhaust of air from the train pipe, about how many air brake cars are coupled to the engine?

Answer 1.—Yes, the longer the train line the longer the exhaust for any given reduction.

Question 2.—Does this give the number of brakes that set or the number of car lengths of train pipe coupled up?

Answer 2.—Only the approximate car lengths of piping coupled up.

Question 3.—What is the difference between an application and a reduction?

Answer 3.—From the time the brakes are applied until they are released, no matter how many reductions, is one application. When they are released and again set, it is another application.

Question 4.—How should a terminal test be made?

Answer 4.—Beginning at the rear, the brakeman should couple all the hose and open all the angle cocks except the one at the rear, see that all the cars are cut in (except such as are marked defective), see that all the hand brakes are off, and the retainers open, with the handles pointing down. The engine should be cut in last. While the engine is charging the cars, the brakemen should pass along the train and inspect it carefully to ascertain if there are any leaks. In charging a train, the pump should be run according to the weather, in order to charge the train reasonably fast without overheating it. Where there are average leaks, an eight inch pump should charge a train in about one-half as many minutes as there are cars; a nine-and-one-half inch pump twice as quickly. After the train is charged and the engineer is

satisfied that it is reasonably free from leaks, the head brakeman (stationed at the head air brake car) should signal the rear brakeman (stationed at the rear air brake car) who should repeat the signal. After the engineer gets the signal from the rear man, he should apply fifteen to eighteen pounds in service application and place the engineer's valve on lap. The brakemen should now walk toward each other, inspecting each car, to see that it sets and holds, noting the piston travel as well. After this has been done, they should signal the engineer to release. Then the brakemen should pass each to his respective end of the air brake cars to see that all the brakes have been released, and, in winter, see that no shoes are frozen to the wheels. The head brakeman should then advise the engineer as to the number of air cars that are in good working order, and the tonnage or length of the train.

Question 5.—With two or more engines coupled to a train, which brake valve should be used to operate the brakes? Which engineer should make the test before starting?

Answer 5.—The one on the leading engine. The leading engineer.

Question 6.—Give the meaning of the various signals made by the air signal whistle.

Answer 6.—This should be answered in accordance with the Code of Rules of the railway by whom you are employed.

Question 7.—How many strokes per minute should an air pump be run to give good service?

Answer 7.—About one complete (up and down) stroke per second, that is, 60 per minute.

Question 8.—How do you cut out a disabled brake?

Answer 8.—With the old style triple valve, by turning the handle on the valve to an oblique position, midway between horizontal and vertical; with all other types of triple valves, by closing the cut-out cock in the branch pipe of the particular car or locomotive brake to be cut out.

Question 9.—How do you operate the straight air brake?

Answer 9.—By placing the handle of the brake valve forward in application position, the application valve is opened admitting air from the main reservoir to the brake cylinders; by placing the handle of the brake valve back in release position, the release valve is opened allowing the air in the brake cylinders to flow to the atmosphere. Lap position is intermediate between these two extremes, and in lap position both valves are closed.

Question 10.—Explain the passage of steam from the boiler through the reducing valve to the steam heat train pipe.

Answer 10.—Most of them operate by the balancing of a spring as against the train pipe steam pressure acting upon a

diaphragm. If the spring be set at any given pressure, say 50 pounds, steam from the locomotive boiler can pass through the valve until there is a trifle more than 50 pounds acting upon the diaphragm; this overbalances the spring and closes the supply until the train line steam pressure falls below 50 pounds.*

Question 11.—If the steam heat gauge shows proper pressure, but the train pipe pressure appears to be low, what should be done?

Answer 11.— See that the steam throttle is open, then increase the tension of the spring in the reducing valve. It may be that the inner lining of some old steam hose is loose and shutting off the free passage of steam to the train; also the rear steam valve on the train may have been left open, or some end valve of a car come loose from its stem.

SUPPLEMENTARY QUESTIONS AND ANSWERS. AIR BRAKE. SECOND SERIES.

Question 1.—What should be done with the air signal apparatus on an engine so equipped which is being used in regular freight service? Why?

Answer 1.—Close the cut-out cock at the reducing valve and only cut it in often enough to test the apparatus and to know it is in order. If this is not cut out the signal appliances all become gummed and dirty more quickly than when in use, and hence would not be available for service when needed.

Question 2.—How can you tell when a plug cock or valve is open or closed?

Answer 2.—By the groove in the top of the plug. It always indicates the direction of the hole in the body of the plug. This groove running crosswise of the pipe indicates closed, lengthwise means open.

Question 3.—Why is this last important to know?

Answer 3.—Because some cocks may have no handle and require to be turned by a wrench, others might have the handle placed on the wrong way.

Question 4.—Why is the brake at present in use called automatic?

Answer 4.—Because the brakes are ordinarily applied on the whole train whenever the train pipe pressure is reduced from any cause whatever—from break-in-two, hose burst,

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* The various types of steam heat reducing valves are illustrated and described in another volume of this series devoted to locomotive appliances.

train pipe broken, conductor's valve, or by the engineer making such reduction.

Question 5.—What are the necessary air brake parts for a locomotive?

Answer 5.—The air pump, pump governor, main drum, auxiliary reservoirs, engineer's brake valve, air gauge, triple valves, brake cylinders, and train pipe, with its cock.

Question 6.—Where are the different pressures stored for use?

Answer 6.—In the main reservoir, auxiliary reservoir, train pipe and equalizing reservoir.

Question 7.—What is the purpose of the pump governor?

Answer 7.—To automatically shut off steam from the air pump when the maximum air pressure is reached and to start the pump again when that pressure has been reduced slightly.

Question 8.—Then, when the pump stops and there is no steam in the pump, what is the cause?

Answer 8.—The governor has shut off the steam.

Question 9.—When the pump stops and there is plenty of steam pressure in the pump (as indicated by drain cocks or other blows) should any attention be paid to the governor?

Answer 9.—No; high pressure steam in the pump shows that the steam has passed the governor and the difficulty is with the pump.

Question 10.—Why do some railroads place a gasket with only a one-half inch opening in the steam pipe to the pump?

Answer 10.—To prevent careless engineers from racing, overheating, and injuring the pump. With 200 lbs. steam pressure this small opening is sufficient supply for the pump to run moderately fast.

Question 11.—What causes the air discharge pipe from the pump to the main drum to become red hot?

Answer 11.—Too much and too poor a quality of oil used in the air cylinder of the pump. This gum is burning out and thereafter the pump will work more freely.

Question 12.—What danger is there from this and how can it be avoided?

Answer 12.—The heat and pressure combined have been known to cause the main drum to explode. By opening the main drum drain cock this can be avoided.

Question 13.—In what other way could this excessive gum be gotten rid of?

Answer 13.—By allowing a pailful of a solution of lye and water to be sucked into the pump and discharged into the drum, then drained out and a pailful of clean water pumped through to cleanse it and drained again.

Question 14.—What other trouble is caused by the use of too much oil in the air cylinder of the pump?

Answer 14.—Defective and gummed up governor, rotary valve, feed or excess pressure valve, signal reducing valve, etc.

Question 15.—What is the result of the continued use of emergency application on an engine in yard or other work?

Answer 15.—The rotary valve gets very dry, becomes cut and the handle moves very hard.

Question 16.—Where are leaks in the train line most likely to be found?

Answer 16.—First, at the hose couplings, due to defective gaskets; second, at the unions in the train pipe; third, through porous hose, and fourth, at the exhaust port of the triple valve, or at the retainers.

Question 17.—In very cold weather what will sometimes cause the pump to stop?

Answer 17.—The discharge pipe frozen up between the air pump and the main reservoir.

Question 18.—Where does this freeze-up usually occur?

Answer 18.—Right where the discharge pipe enters the main reservoir. Begin to thaw out there and you usually have the whole trouble obviated.

OIL BURNING LOCOMOTIVES.*

Question 1.—What are the fireman's duties on arrival at engine house previous to going out with an oil-burning engine?

Answer 1.—It is his duty to see that the heater is adjusted and the oil is heated sufficiently and that the oil is in condition to flow freely to the burner.

Question 2.—How warm should oil be at all times in tank?

Answer 2.—The best results are obtained when the oil is heated to such a temperature that the hand can be held on the tank, or to about 110 degrees, Fahrenheit.

Question 3.—If the oil is too warm what happens?

Answer 3.—Some of the qualities of the oil are lost by the constant boiling and the burner does not work so well and will make it more difficult to operate.

Question 4.—What tools are necessary for firing purposes on an oil-burning engine?

Answer 4.—The necessary tools allowed by the railroad for which you are working.

Question 5.—What is liable to happen if heater valve is open too much?

Answer 5.—It is very apt to burst a hose.

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*The reader is referred to the chapter herein devoted to this subject.

Question 6.—What should be done on approaching oil supply stations, where additional supply of fuel oil is to be taken?

Answer 6.—See that there are no lamps or lights on the tender when you stop.

Question 7.—What care must be exercised in the use of lamps, torches or lanterns about oil tanks, whether hot or cold? Why?

Answer 7.—Do not carry, or permit any one to carry, oil lamps or oil torches within a distance of ten feet of tank opening.

Question 8.—How should depth of oil in tank be measured without taking a light to manhole?

Answer 8.—By the gauge.

Question 9.—What precaution must be taken before entering tanks that have been used for oil, to clean or make repairs?

Answer 9.—You should not enter tanks until they have been thoroughly cleansed.

Question 10.—How should the fire be lighted in oil-burning engines?

Answer 10.—See that the boiler is properly filled by trying the gauge cocks when the fire is lighted in the round house. Steam connection can be made to the three way cock on the smoke arch which will act as blower and atomizer. If you have steam on engine, 20 or 30 pounds, it can be operated with its own blower. See that the front of the fire box is free from carbon or anything that would obstruct it from burning; it must have free passage so oil can get to burner. Open the front damper, put on the blower strong enough to make the necessary draft, open the atomizer valve long enough to blow out any water which might be in steam pipe or burner; next close the valve and throw a bunch of lighted old waste in front of the burner, then open the atomizer sufficiently to carry oil to the waste and open the regulator slowly until the oil is known to be ignited—this you can see through the fire-box door.

Question 11.—Should the fire go out and it is desired to re-kindle it while bricks are hot, is it safe to depend on the hot bricks igniting the oil without the use of lighted waste?

Answer 11.—No, always use waste in re-kindling the fire as the bricks are not very reliable and apt to do damage from explosive gases formed.

Question 12.—What is termed an atomizer, and what duties does it perform?

Answer 12.—The atomizers are made of brass, 12 inches long, 4½ inches wide and 2 inches thick from top to bottom, divided into two parts by a partition in the middle; they

separate the oil into a fine spray and blow it into the fire-box. The atomizer is located just under the mud ring, pointed a little upward, so the stream of oil and spray of steam will strike the opposite wall a few inches above the bottom if it were to pass clear across the box. Deep fire-boxes have the atomizer at the back end of the box, while the shallow and long fire-boxes have it located at the front end, pointed back.

Question 13.—In starting up or shutting off throttle of an engine, how should the fireman regulate the fire, in advance or after the action of the engineer?

Answer 13.—In advance of the engineer's action.

Question 14.—Is it, therefore, necessary that the fireman and engineer on an oil-burning engine work in perfect harmony, and advise each other of intended action at every change of conditions?

Answer 14.—Yes, they should work in harmony with one another and while the fireman should watch every move the engineer makes it is also the duty of the engineer to advise the fireman of every change of the throttle so that he can operate his valves according therewith and thus save fuel.

Question 15.—What is the effect on a fire-box of forcing the fire on an oil-burning locomotive?

Answer 15.—It will cause the flues to leak. Always keep an even temperature in the fire-box.

Question 16.—Is a careful regulation of steam and oil valves and dampers necessary to obtain the most economical results?

Answer 16.—Yes, the firing valve should be opened sufficiently to make it certain that enough oil is being fed to produce a good fire, but not enough to cause a great volume of black smoke.

Question 17.—How can you judge whether the combustion is good or bad, so that the valve may be regulated accordingly?

Answer 17.—By noting the smoke emitted from the stack.

Question 18.—How should flues be cleaned from soot when running, and about how often is it necessary?

Answer 18.—The flues should be cleaned out after leaving terminals, or after an engine has been standing for some time. The use of the sand, frequently and in small quantities, is recommended.

Question 19.—Is the injudicious use of the blower particularly injurious to an oil-burning engine?

Answer 19.—Yes, the frequent use of the blower is injurious to a fire-box and the cold air drawn in through the flues will cause them to leak.

Question 20.—Is the blower more injurious when a light

smoke is emitted from the stack, or when a black smoke is emitted?

Answer 20.—It is more injurious when a light smoke is emitted from the stack.

Question 21.—In drifting down long grades should fire be shut off entirely or burned lightly? Why?

Answer 21.—The fire should be burning lightly, yet it should not be permitted to get too low, allowing the fire-box to lose its temperature and thus causing the flues to leak.

Question 22.—How should the fire be handled when switching?

Answer 22.—It should be used the same as when running.

Question 23.—Would not some fuel be wasted in this manner?

Answer 23.—Very little will be wasted if the fireman watches closely.

Question 24.—How should fire be handled leaving stations?

Answer 24.—It should be burning brightly and sufficiently strong to keep from going out.

Question 25.—Which is desirable—to use as much or as little steam-jet atomizer as possible?

Answer 25.—Use as little atomizer as possible at all times.

Question 26.—What is the result of too little steam atomizer, when standing at stations, or engine working light?

Answer 26.—It is very apt to allow the fire to go out.

Question 27.—If too much steam atomizer is used with little fire?

Answer 27.—It will use too much steam and reduce the temperature of the fire-box.

Question 28.—When the fire kicks and smokes what should be done?

Answer 28.—The blower should be put on and the dampers closed.

Question 29.—How should the dampers be used on an oil-burning engine?

Answer 29.—They should be closed when drifting to prevent cold air being drawn in, causing flues and stay-bolts to leak.

Question 30.—About how much smoke do you consider an oil-burning engine should make under adverse conditions, when engine is steaming well, but is being crowded by engineer to make up time?

Answer 30.—No more than when an engine is working ordinarily.

Question 31.—What color is most desirable at peep holes in fire-door?

Answer 31.—A bright, ruddy color.

Question 32.—What will produce a ruddy color?

Answer 32.—By feeding only the amount of oil that is properly burned and watching the regulating valves closely.

Question 33.—How does water in oil affect the fire?

Answer 33.—It affects the flame and requires more oil than otherwise.

LUBRICATION.

Question 1.—What produces friction, and what is the result of excessive friction?

Answer 1.—The rubbing together of any two surfaces. The result is heat.

Question 2.—What is lubrication and its object?

Answer 2.—The interposing of a thin layer of a lubricant so that the surfaces do not actually touch each other—the oily surface of one part slides with less heat against the oily surface of the other.

Question 3.—What examination should be made by engineer to insure successful lubrication?

Answer 3.—He must examine so as to know that the oil holes are open, packing clean and feel of all bearings to find if any foreign substance is affecting the lubrication. He must also give careful attention to the lubricator.

Question 4.—How should feeders of all oil-cups be adjusted?

Answer 4.—They should be adjusted according to the work and the temperature, closing them at terminals if they feed from the bottom of the cup.

Question 5.—Why is it bad practice to keep engine oil close to boiler in warm weather?

Answer 5.—It gets too hot and will flow off of the bearings too readily. Besides, many times the oil needs thinning rather than heating in cold weather.

Question 6.—In what manner would you care for hot bearings when discovered on the road?

Answer 6.—If due to pounding, tighten up. If too tight, let up on wedge bolt or rod key. See that they are kept well oiled, cool them down if too hot to stand the grade of oil used; repack cellars and remove journal bearings in engine or tender trucks if necessary.

Question 7.—What kind of oil should be used on hot bearings?

Answer 7.—If too hot to stand engine oil and no time to cool down, use valve oil or grease.

Question 8.—At completion of trip what is necessary?

Answer 8.—Shut off the lubricator and all bottom feed oil cups, feel of all bearings and pins and report any that are running hot.

Question 9.—How would you determine what boxes to report examined? Why not report all boxes examined?

Answer 9.—Never report more than is necessary. Feeling of the bearings shows which are running too hot—report those examined or packed.

Question 10.—Why is it bad practice to disturb the packing on top of driving and engine truck boxes with spout of oil can when oiling engine?

Answer 10.—It stirs up the dirt, cinders and sand and is liable to get them down on the bearing.

Question 11.—How do you adjust grease cups as applied to rods?

Answer 11.—By screwing down the compression plug until the grease appears at the bearing. After a little experience on a given engine a man can tell just how much of a turn to give each plug to insure safe running. Taking hold of the rod, it will bind a little if the grease has fed down solid.

Question 12.—Is it usual for pins to run warm when using grease?

Answer 12.—Yes, for the grease must melt and become practically an oil in order to lubricate freely.

Question 13.—What effect does too much pressure produce?

Answer 13.—It wastes the grease and increases the friction.

Question 14.—Is it necessary to use oil with grease on crank pins?

Answer 14.—No.

Question 15.—Why should engine oil not be used on valves and cylinders?

Answer 15.—Because it will vaporize and become like a gas which has no lubricating qualities at such a high temperature as that of the steam.

Question 16.—At what temperature does engine oil lose its lubricating qualities? Valve oil?

Answer 16.—From 200 to 300° F. At from 400 to 600° F.—depending upon the quality of the oil.

Question 17.—How and by what means are valves, cylinders and air pumps lubricated?

Answer 17.—By lubricators.

Question 18.—How should lubricator be filled?

Answer 18.—Shut off the steam, remove the filling plug, open the drain cock and draw off the water only. Then fill the lubricator from the tallow pot.

Question 19.—After filling lubricator what should be done?

Answer 19.—Open the main steam valve and condenser valves and wait until sufficient water has condensed; then open the feeds as required.

Question 20.—How long before leaving terminal should feed valves be opened?

Answer 20.—Just before starting.

Question 21.—How many drops should be fed per minute?

Answer 21.—Five to ten drops per minute for cylinders, depending upon conditions. About one drop per minute for the air pump.

Question 22.—Why is it bad practice to carry water too high in boiler?

Answer 22.—It washes most of the oil off the valves and the cylinder walls and is liable to cause cutting.

Question 23.—When valves appear dry when using steam, and lubricator is working all right, what would you do to relieve conditions?

Answer 23.—Ease off on the throttle and drop the lever down a little for a few strokes. If too much water in the boiler, blow off some.

THIRD SERIES OF QUESTIONS AND ANSWERS.

Question 1.—What are the duties of an engineman before attaching the locomotive to the train?

Answer 1.—The duty of the engineman is to thoroughly inspect his engine for possible defects of machinery. He should know the condition of the fire-box, grates, etc.; that gauge and water glass cocks are open and working freely. that the crown sheet is covered with sufficient water to protect it from injury, and that the tender has been supplied with fuel and water. He should also know the condition of the engineer's brake valve and air pump, and take such other precautions as would prevent an engine failure.

Question 2.—What tools should there be on the locomotive?

Answer 2.—The engine should be provided with such tools as are found necessary in everyday work. This includes also tools with which to make repairs in case of accident. Clinker bar, ash-hoe, coal pick, shovel and broom are classed as tools.

Question 3.—What examination should be made after any work, or repairs have been done on valves, brasses, etc.?

Answer 3.—A man should satisfy himself by personal

inspection that the work has been properly done, that all movable parts have been returned to place and properly secured by set screws or otherwise.

Question 4.—What attention should be given to boiler attachments, such as gauge cocks, water glasses, etc.?

Answer 4.—It should be known that they are open and working freely at all times.

Question 5.—Trace the steam from the boiler through the cylinders to the atmosphere, and explain how it transmits power.

Answer 5.—From the main throttle in the dome into the dry pipe, then through the steam pipes into each steam chest. From there through the admission port into one end of the cylinder, forcing the piston to the opposite end. When the piston has nearly completed its stroke, the movement of the valve (which is in the opposite direction to that of the piston) opens a connection to the exhaust port and allows the steam from the cylinder to pass through this exhaust cavity into the exhaust pipe, through the nozzle, the stack and out into the atmosphere.

Question 6.—Why is it important that there be no holes through smoke-box sheets, or front end, and none in smoke-box seams or joints?

Answer 6.—There should be no possible chance for the admission of air to any part of the smoke-box, because it tends to destroy the vacuum necessary to create a perfect draft on the fire and also fans any fire that may be in the smoke-box, which warps and destroys the sheets or front-end.

Question 7.—How should the locomotive be started to avoid jerks, and what train signals should be looked for immediately after starting?

Answer 7.—The engine should be started with the reverse lever in full gear in the direction in which the locomotive is expected to move, and a gradual admission of steam to the cylinders. Signals should be carefully looked for towards the rear end of the train to make sure that the entire train has been started.

Question 8.—After a locomotive has been started, how can it be run most economically?

Answer 8.—By working steam expansively, that is, with the reverse lever hooked back to a point where the engine will handle her train with a full or nearly a full throttle.

Question 9.—What is meant by "working steam expansively"?

Answer 9.—By working steam expansively is meant the process by which steam is let into the cylinder and cut off before the piston has finished its full stroke, thereby

allowing the expansive force of the steam to exert a certain amount of energy upon the piston from the time that cut-off took place up to the point where release occurs.

Question 10.—How rapidly should water be supplied to the boiler?

Answer 10.—Water should be delivered to the boiler steadily and in just sufficient quantity to replace the water which has been evaporated in doing work.

Question 11.—What is the difference between priming and foaming of a locomotive boiler?

Answer 11.—Priming is caused by the boiler being too full of water and has a tendency to raise the water in a solid mass, while foaming is caused by foreign substances in the water, such as oil, soap, alkali, etc. In both cases water is carried with the steam to the cylinder.

Question 12.—What should you do in a case of foaming? What in case of priming?

Answer 12.—The throttle should be either partly or entirely closed for a few moments to ascertain the water level in the boiler. Where surface cocks are used, they should be used while the engine is at work, because they will then carry away the scum which has been driven to the surface. When recourse is had to the blow-off cock, it can best be done when the engine has been shut off, as the sediment then settles to the bottom. In case of priming, lower the water level and keep it lower thereafter.

Question 13.—What danger is there when the water foams badly? When it primes badly?

Answer 13.—From foaming there is danger of exposing the crown sheet to the intense heat and the liability of burning it. From priming there is danger of knocking out a cylinder head.

Question 14.—What work about a locomotive should be done by the engineman?

Answer 14.—He should set up the wedges and key up the rod brasses and see that all nuts and bolts are tight.

Question 15.—How should the work of setting up the wedges be done?

Answer 15.—The engine should be placed with the crank pin of the right side on the upper, forward eighth, which brings the crank pin of the left side on the back, upper eighth. Block the wheels, and with the reverse lever in the forward motion apply a small quantity of steam. As the action of the steam against the piston has a tendency to move it forward, the strain is thrown against the shoes, permitting a free movement of the wedges. The wedges should be set up with an ordinary wrench as far as possible and then pulled down again about one-eighth of an inch to

prevent the box from sticking either from over-heating of the box or defective lubrication of the wedge.

Question 16.—How should rod brasses be keyed?

Answer 16.—The key should be driven down just enough to bring together brass to brass. Any greater force would spring the crown of the brass against the pin and cause it to heat.

Question 17.—How should an engine be placed for the purpose of keying the rod brasses?

Answer 17.—That depends entirely upon which rods are to be keyed. If the main rod is to be keyed, place the side of the engine upon which the work is to be done either on the upper forward eighth or the lower back eighth, as these positions present the greatest diameter of the pin to the rod brass and guarantee a free movement at all points without binding.

Question 18.—What is the necessity of keeping brasses keyed up properly?

Answer 18.—To prevent unnecessary shocks and heating of rod brasses and pounding in driving boxes, which in time cause undue strain on the entire engine with disastrous consequences.

Question 19.—How should the side rods on a mogul or consolidation locomotive be keyed?

Answer 19.—Place the engine on the dead center either forward or back. First key the middle connection, next the ends of rods and observe that the rod moves freely on the pin. Now place the engine on the opposite dead center and notice if the rods move freely at this point also. This is particularly necessary with rod brasses having keys on both sides of the pin and which are apt to be made either too long or too short, throwing the rods out of tram and causing undue strain on rods and driving boxes, and also danger of broken rods or pins.

Question 20.—What is meant by "engine out of tram"?

Answer 20.—By an engine out of tram is meant one whose distance from center to center of axle or rod on one side does not coincide with the similar distance on the opposite side; or it may mean that the distance between two connected crank pins is not the same as the distance between the two axles to which the crank pins belong.

Question 21.—Describe a piston valve.

Answer 21.—A piston valve is a cylindrical, spool-shaped device having cast iron packing rings sprung into place on the valve, and operating in a cylinder of equal diameter. The valve cylinder is provided with suitable admission and discharge ports, and permits the valve to perform the same functions as an ordinary slide valve

Question 22.—What is a balanced slide valve? How is it balanced, and why? For what purpose is the hole drilled through top of the valve?

Answer 22.—A balanced slide valve is one where a certain percentage of the steam pressure exerted on the top of the ordinary slide valve has been removed. The balancing feature is obtained by a steam table extending beyond the extreme travel of the valve, and either bolted to the steam chest cover or cast in one piece with it. The Allen-Richardson valve has its valve grooved for the reception of four snugly fitting strips which are supported against the table by semi-elliptic springs, which makes a steam-tight joint and prevent any considerable pressure reaching the enclosed part of the valve. The American balanced valve obtains the same results but uses circular tapering rings supported by coiled springs. The small hole in the top of the valve is for the express purpose of allowing any pressure which may have accumulated on the top of the valve from whatever cause to escape to the exhaust port.

Question 23.—What is meant by inside and outside admission valves?

Answer 23.—By inside admission valve is meant one where the steam enters the steam port of the cylinder from the inside edge of the valve and is exhausted from the outer edge of the valve; by outside admission is meant one where steam enters the steam port from the outer edge and is exhausted from the inner edge, similarly to our common slide valve, which is an outside admission valve.

Question 24.—What is the relative motion of main piston and valve for inside admission valve, and for outside admission valve?

Answer 24.—With inside admission the motion of the valve is in the opposite direction to the piston's motion at the beginning of the stroke. With outside admission the movement of the valve is in the same direction as the piston at the beginning of the stroke.

Question 25.—What is an Allen ported valve, and what is its object?

Answer 25.—An Allen ported valve is a D slide valve having an auxiliary port cored in the valve and extending nearly from one edge of the valve to the other. The object of this port is to give rapid admission of steam to the cylinder; also in some instances it is so designed as to give a more rapid exhaust.

Question 26.—What is the difference in the valve motion for outside admission valves, for inside admission valves?

Answer 26.—Both may have either direct or indirect mo-

tion according to the position of the eccentrics on the shaft and the type of rocker arm used.

Question 27.—What is a direct motion valve gear? What is an indirect motion valve gear?

Answer 27.—A direct motion valve gear is one that transmits the motion of the eccentric to the valve direct by means of a transmission bar or a rocker shaft upon which both rocker arms hang suspended in the same direction. An indirect motion valve gear is one where the power is transmitted from the eccentric to the lower rocker arm, which by its motion forward forces the upper arm backward, so that the travel of the eccentric is diametrically opposite to the travel of the valve.

Question 28.—What is meant by lead?

Answer 28.—Lead is the amount of opening a valve has when the piston is at the beginning of its stroke.

Question 29.—What is meant by steam lap?

Answer 29.—By steam lap is meant the amount the valve overlaps the steam ports, when the valve is in the center of its seat.

Question 30.—What is meant by exhaust lap, and by exhaust clearance?

Answer 30.—Exhaust lap is the amount the inner edge of the valve overlaps the steam ports when the valve is in the middle of the seat. Exhaust clearance is the amount the inside edge of the valve comes short of covering the ports when the valve is in the middle of its seat.

Question 31.—With an indirect valve motion, what would be the position of the eccentric relative to crank pins? With direct motion valve gear? With outside admission valves? With inside admission valves?

Answer 31.—If the valves are the inside admission indirect, necessitating a rocker shaft, the eccentric would lean toward the fire-box when the main pin is on the forward dead center; while an outside admission, indirect, has the belly of the eccentrics leaning toward the main pin. With an inside admission direct and a transmission bar, both eccentrics lean toward the pin; while with the outside admission direct the eccentrics have the same position as with the inside admission indirect. With the inside admission indirect the eccentric rods are crossed, when the crank pin is on the forward dead center; the eccentric rods with the outside admission direct are also crossed when the crank pin is on the forward dead center. These positions of the eccentrics are necessary with the corresponding valve motions to secure correct movement of the valves.

Question 32.—What effect would be produced upon the lap and lead by changing the length of eccentric rods?

Answer 32.—Changing the length of the eccentric rods will either increase or decrease the travel or produce an uneven travel of the valve over the ports, causing either a too early or too late admission and release. It depends entirely on whether one or both rods have been shortened or lengthened. It affects the engine in that a too early admission on one end would give a too early release, and a too late admission a too late release on the other end. Changing the lengths of the eccentric rods does not affect the valve lead. Positive lead can only be obtained by advancing the eccentric toward the pin with the ordinary slide valve and indirect motion, while negative lead under similar conditions requires the eccentric to be turned from the pin.

Question 33.—Why are eccentric rods made adjustable?

Answer 33.—To allow for adjustment of the valve travel so that even steam admission may be made at both steam ports.

Question 34.—Why is it necessary to keep the cylinders free from water?

Answer 34.—To prevent rupture of the cylinder and its head which would necessarily occur should much water remain after the valve had closed all communication and the piston been forced to the end of its stroke, especially with piston valves which cannot be lifted off their seat, as can slide valves.

Question 35.—Where is piston rod packing located? Where cylinder packing?

Answer 35.—The piston rod packing is located in the back cylinder head. Cylinder packing is to be found in the grooved receptacles provided for that purpose in the circular surface of the piston.

Question 36.—How are metallic packing rings on valve stems and pistons usually held in place? What provisions are made for the uneven movement of rods?

Answer 36.—Metallic packing rings are held in place by stiffened spiral springs pressing against a ring and forcing the packing into a bell-shaped cone. Suitable provision is made for the uneven movement of the rods in that the cone holding the metallic packing has a ground and steam tight joint, which permits the cone to have a lateral motion against the face of the packing gland, and thereby prevents the escape of any steam.

Question 37.—What is cause of tank sweating and what will prevent it?

Answer 37.—Variations of atmospheric conditions. The temperature of the water in the tank being of a lower degree than that of the surrounding atmosphere, condensation from

the moisture in the air takes place on the exterior of the tank. It can be prevented by bringing the water in the tank to the same temperature as the surrounding atmosphere.

Question 38.—Explain the construction and operation of the blow-off cock.

Answer 38.—A blow-off cock may be either a glove valve operated by a screw, a taper plug valve operated by a lever, a sliding disk valve operated by a lever, or a plunger valve upon whose upper end either steam or air may be forced to unseat it. The object of any of these valves when opened is to permit the escape of sediment and impurities from the boiler, and for that reason they are located at the bottom or "legs" of the boiler.

Question 39.—Describe a bell ringer, and how it can be adjusted.

Answer 39.—The automatic bell ringer is a device whose mechanism consists of a valve having either a sliding or rotary movement and provided with a suitable admission and exhaust port, a piston operated in a cylinder, and a piston rod connected to the bell crank so as to impart a swinging movement. The motive power is air taken from the main reservoir, or steam from the boiler. Some types are provided with a threaded stem and a jam nut by which adjustment can be made.

Question 40.—In case a locomotive in your care became disabled on the road, what should you do?

Answer 40.—First, protect the train front and rear by flags the prescribed distance. Make such temporary repairs as are necessary to get the train to the next siding, in order to prevent blockading of the main line. When on the siding make all the repairs practicable with the tools at hand. If the breakdown is of such a nature as to prevent the possibility of making even temporary repairs so as to clear the main lines, arrange to notify the nearest telegraph office of your location and ask for assistance, giving full particulars.

Question 41.—Suppose a wash-out plug blew out, or a blow-off cock would not close, what would you do?

Answer 41.—First put both injectors to work and endeavor to overcome the leak until you can get in to clear. That failing, draw the fire at once to prevent burning of fire-box sheets. In addition to this, in cold, freezing weather, the pet cocks on all connections where there is any liability of water collecting should be opened to drain the pipes, and in the absence of cocks the couplings should be slacked off. The tender hose couplings should be disconnected and special care should be given to the air pump drain cocks to prevent the rupture of the steam cylinder of pump.

Question 42.—What should be done if grates be burned out or became broken while out on the road?

Answer 42.—Block up the broken or burnt grates with fish-plates, brick or anything conveniently at hand, and disconnect the good grate immediately ahead and back of the burnt section in order to prevent disturbing the other grates when shaking down the fire.

Question 43.—What precaution should be taken to prevent locomotives throwing fire?

Answer 43.—In order to prevent engines from throwing fire the netting in the smoke arch must be carefully looked after, and the cinder slide and hand-hole plates must be in their proper places and securely fastened. Equally important is the knowledge that the ash pan is clean, otherwise live coals, more dangerous than cinders, will roll out of the pan and start fires on bridges and along the company's property.

Question 44.—What should be done with a badly leaking or bursted tube?

Answer 44.—Where time and conditions permit, burst flues can be put in condition to bring in train. First, fill the boiler as full of water as it will hold, to compensate for loss. Then blow off steam through the whistle or remove release valve from chest, open the throttle, and blow off steam and deaden the fire so that the flue can be plugged. If the flue is burst, it must be plugged at both ends. If it is simply a case of leaky flue at flue sheet, the above is not necessary—simply plug the flue. Bran or any starchy substance admitted through the heater cock on the injector after the injector has been started will aid in stopping a bad leak.

Question 45.—Suppose that, immediately after closing the throttle, the water disappeared from water gauge glass, what should be done?

Answer 45.—Disappearance of water from water glass may be caused in various ways. The water may be bad and foamy, or the engine may have insufficient steam space, thus causing the water to prime, or the engineer may have taken too many chances on low water. As soon as the water disappears from the glass no time should be lost before banking or deadening the fire. The injectors should be kept at work until the water reappears in the glass before fire is rekindled.

Question 46.—What should be done in case the throttle valve stem became disconnected while valve is closed? If it became disconnected while open?

Answer 46.—With a disconnected throttle closed—where the company requires the engineman to make repairs—steam must first be blown off and the dome cap raised to reach the disconnected rod. Not enough power can be had from the

oil pipes to move the modern engine. If she is equipped with a drifting valve, she can be made to move herself without any train. If the throttle is disconnected and open, reduce pressure to a point where the engine will not slip, and control the train by air brake. What is often mistaken for a disconnected throttle is merely a stuck throttle due to excessive lost motion of parts and occurs when giving full throttle. Tapping the throttle rod often releases it from sticking.

Question 47.—In case a slide valve yoke or stem became broken inside of steam chest, how can the breakage be located?

Answer 47.—After satisfying myself that the eccentrics and visible parts of the valve motion were intact, I should consider the type of valve on the engine. With a broken valve stem or yoke, the valve is always forced to the forward end of chest. With an outside admission piston valve or a slide valve, place the lever in the forward gear and watch the steam leaving the cylinder cocks. Reverse the lever, and if the steam issues from both cocks on one side and from only the back one on the other, the latter has the disabled valve. With the inside admission, steam would issue from the front and not from the back cylinder cock. Where relief valves are used I would remove them first and watch movement of valve.

Question 48.—After locating a breakage of this kind, how should one proceed to put the engine in safe running order?

Answer 48.—If the engine had relief valves on the front end of the steam chest, disconnect valve rod; and, after forcing valve to central position to cover ports, clamp stem from one end and block with a plug driven into relief valve of sufficient length to hold the valve in place, leave up main rod and proceed. If relief valve were on the back end, the chest cover would not have to be taken up, but the back end of main rod would have to be disconnected and crosshead blocked ahead. The disconnected valve rod would hold the valve against the forward end of the steam chest.

Question 49.—If a slide valve is broken, what can be done to run the engine with one side?

Answer 49.—If it is a balanced valve and broken so that the steam ports cannot be successfully covered, slip a heavy piece of sheet iron between valve and valve seat, and block valve front and aft. The balance plate will then come down solid on valve and prevent leakage to the cylinder. With the ordinary slide valve and similar conditions, remove valve entirely and block with hard wood having the grain of the wood crosswise of the seat. With the sheet iron over the seat and the chest filled with blocking so that the cover will close down on it firmly and make a steam-tight joint, pro-

ceed on one side without disturbing anything except the valve rod.

Question 50.—What should be done in case of link saddle pin breaking?

Answer 50.—Put the lever in a notch forward where one would be safe in starting a train. Then raise the link on the disabled side to the same level as the good one and block between top of the link block and the link. Have another block ready of sufficient length to raise the link enough should it be necessary to back up the engine.

Question 51.—With one link blocked up, what should be guarded against?

Answer 51.—Reversing the engine, unless the disabled side has been changed by raising or lowering to correspond with the good side.

Question 52.—How can it be known if the eccentric has slipped on the axle?

Answer 52.—By a lame exhaust or, with a bad slip, one of the exhausts disappearing entirely, and by watching the crosshead to note when the exhaust takes place.

Question 53.—Having determined which eccentric has slipped, how should it be re-set?

Answer 53.—Having located the eccentric, if it is a go-ahead, move the engine so that the crosshead will come very near to the end of its travel ahead. Then move the eccentric around pointing in the opposite direction to the back-up, leaning either toward or from the pin—which would depend entirely on the style of valve and whether direct or indirect motion. As soon as steam appears at front cylinder cock, tighten the set screws. For a back-up eccentric, lever and crosshead will have to be placed in the opposite direction. The best way is to mark the eccentrics before starting, by placing the lever in forward notch and having crosshead at front end of travel. Then make a mark on the crosshead and the guide, doing the same with eccentrics and straps. If from any cause an eccentric slips and the engine is placed so that the mark on the crosshead corresponds with that on the guide, the marks on three of the eccentrics will correspond with those on the straps, while the fourth or slipped eccentric's mark will be some distance away from the mark on its strap. By this method an eccentric can be set as true as any machinist can set it, and there is no guesswork.

Question 54.—What should be done in case of a broken eccentric strap or rod?

Answer 54.—Take down the other strap and rod, cover ports and leave main rod intact.

Question 55.—How should the engine be disconnected if lower rocker arm became broken? If link pin?

Answer 55.—Unless the link interferes, all that is necessary is to remove the broken part of the arm, cover ports by placing valve in its central position and leaving the main rod up; otherwise the eccentric straps and rods would have to come down. With a broken link block pin, there is more or less danger of interference between the link and the rocker arm. Take down the eccentric straps and rods only, and cover the ports.

Question 56.—What would be considered a bad engine or tender truck wheel?

Answer 56.—One with sharp flange, or flat or shelled-out spots in tread of wheel, 2½ inches or more in length.

Question 57.—What should be done if an engine truck wheel or axle should break?

Answer 57.—It should be entirely removed or blocked up so as to have the wheel clear of the rail, and the truck frame should be securely fastened to the engine frame with chains.

Question 58.—What should be done if a tender truck wheel or axle should break?

Answer 58.—The same as with the engine truck wheel and fasten the truck frame with chains to the tender frame. Move slowly and cautiously to a point where repairs can be made.

Question 59.—How should an engine be blocked for a broken engine truck spring or equalizer? For a broken tender truck spring?

Answer 59.—If the pilot will not be too low, let the truck frame ride on the boxes; otherwise, block between the top of the boxes and the truck frame. Blocking for a broken tender spring will vary according to the type of truck used. Some have a coil spring over each axle box and are easily taken care of; some have semi-elliptic springs with the spring band against the tender frame and the ends of the spring resting on the arch bar over the axle boxes while others have elliptic or coil springs supporting the truck bolster and resting on the sand plank. With the first, block over the individual box; with the second, between the truck bolster and the tender frame; and with the third, between the truck bolster and the sand plank.

Question 60.—For what breakdowns is it necessary to take down the main rods? The side rods?

Answer 60.—With regard to taking down the main rod, instructions differ on the various railroads and an engineer should ascertain from the Traveling Engineer, Road Foreman, or Master Mechanic what is their practice. Where very large power is used it is practically impossible for two men to take down and load up a main rod. But when the main rod is left up, be sure to leave good openings in the cylinder

and oil the latter well. As regards side rods, if one is broken or has to come off, take down the same rod on the opposite side; also remove rods on both sides with knuckles in them, provided the next section of side rod is disabled.

Question 61.—If it is not necessary to take down the main rod on disabled side of the engine how would you arrange to lubricate the cylinders?

Answer 61.—By removing the indicator plugs, if the engine is equipped with them, oiling through them and replacing the plugs. If the engine has no plugs, shift the valve just enough to show a little steam at the cylinder cocks and oil with the lubricator.

Question 62.—What should be done if a driving spring, spring hanger or equalizer should break?

Answer 62.—Remove the broken parts and block over the box affected by the break; as to blocking the equalizers properly, be governed by the type of spring rigging used.

Question 63.—How can an engine be moved if the reverse lever or reach rod were caught at short cut-off by a broken spring or hanger?

Answer 63.—By disconnecting the tumbling shaft arm and blocking over the link block pin with blocking that would permit sufficient power to be used to start the train.

Question 64.—How can blowing of steam past a valve, cylinder packing or valve strip be distinguished and located?

Answer 64.—When the valve has been placed to cover both steam ports and no steam escapes from the cylinder cock but escapes through the exhaust port to stack, it indicates that valve strips are down or broken and permits steam to escape through the small hole in the valve to the exhaust port. If the valve covers the ports and steam appears at both cylinder cocks, it indicates a cut valve or seat. If a piston is at the beginning of stroke and the valve uncovered and steam escapes from the cylinder cocks at the opposite end also from which it is admitted, it indicates leaky packing rings or cut cylinder. A valve blow continues during the entire travel of the valve, while a cylinder blow is strongest when the piston is at beginning of its stroke and gradually diminishes until cut-off takes place as the piston nears end of its stroke.

Question 65.—If an engine should blow badly, and be unable to start the train when on the right hand dead center, on which side would be the blow generally?

Answer 65.—On the left side, since that is the only power the engine has to move the other side off the dead center.

Question 66.—If throttle were closed and steam came out of cylinder cocks, what might be the cause?

Answer 66.—Leaky throttle or dry pipe.

Question 67.—Is it possible to distinguish between a leaky throttle and a leaky dry pipe?

Answer 67.—Yes, a leaky throttle will show dry steam only, while with a leaky dry pipe more or less water will pass out of the cylinder cocks with the steam when the engine is standing, and when the engine is working she appears to be working water all the time, particularly with a full boiler of water.

Question 68.—What effect have leaky steam pipes, and how should they be tested?

Answer 68.—They interfere with the draft on the fire and prevent the engine from making steam. Place the lever on the center, set the air brake, open the throttle and watch the joints of the steam pipes top and bottom. The proper test is the hydraulic test made in the shop.

Question 69.—How should the test for a leaky exhaust pipe joint or a leaky nozzle joint be made?

Answer 69.—By placing the lever forward or back and moving the engine slowly with brakes set and watching the joints. Cinders never accumulate around such leaks and are always driven away from them.

Question 70.—What should be done if a steam chest cracks?

Answer 70.—If the crack is not too serious, temporary relief can be obtained by driving wedges between the chest bolts and steam chest.

Question 71.—What should be done if a steam chest breaks?

Answer 71.—That depends on the type. With the chest commonly used, take up the chest cover, insert blocking in the steam passages to chest and bolt the cover down firmly upon them.

Question 72.—If a link lifter or arm were broken, what should be done?

Answer 72.—Block the same as for broken link saddle pin.

Question 73.—If the reverse lever or reach rod should break, what should be done?

Answer 73.—Follow the same method as for broken link saddle pin.

Question 74.—What should be done if the piston, crosshead, main rod, or crank pin is bent or broken?

Answer 74.—If the piston is broken or the piston rod bent, remove both, disconnect valve, the stem only, and cover ports. With a broken crosshead or bent or broken main rod, the main rod would have to come down. Then, push the piston ahead or back—this depends on the type of engine—and the shift valve to force steam against the piston in the direction in which it was desired to hold the piston; clamp

the valve and block the crosshead as an additional precaution. With a broken crank pin the rod would not have to come down, but could rest on the yoke or guide. First ascertain in the case of a piston valve whether it is an inside or outside admission before shifting, as the movement of the former is directly opposite to that of the latter.

Question 75.—What should be done if a safety valve spring breaks?

Answer 75.—Remove the spring and block between the valve and its cap, allowing the other valve to do the work.

Question 76.—What should be done when there is a loose or lost cylinder key?

Answer 76.—If the key is loose and can be shimmed up, it is safe to go on. If the key is lost and nothing available, such as track spike or cold chisel, in its place, disconnect that side to prevent further damage.

Question 77.—How can an engine be brought in with a broken front end or stack?

Answer 77.—By boarding up and by protecting it with the canvas cab curtain. Placing a barrel on the smoke arch in lieu of a stack will answer the purpose, but on a road with heavy traffic such expedients are not practicable.

Question 78.—What should be done if a frame is broken between the main driver and cylinder?

Answer 78.—The safest plan is to be towed in dead. The other alternative is to disconnect the disabled side and bring the engine in light, because an attempt to bring in part of the train might damage the previously uninjured side.

Question 79.—What should be done if a frame is broken back of main driver?

Answer 79.—Take down side rods on both sides back of main driver and proceed.

Question 80.—In case of broken side rods what should be done?

Answer 80.—Take down corresponding rod on opposite side also, and, if it is a consolidation, mogul or ten-wheel engine and the intermediate rod is broken, all side rods would have to come down.

Question 81.—What can be done if the intermediate side rods were broken on a consolidation engine, having the eccentric on the axle ahead of main wheel?

Answer 81.—There is nothing to be done but be towed in, unless only one side is broken; when it would be possible to bring the engine in under her own steam on one side, with the disabled side having its valve disconnected and ports covered, but this is not advisable, inasmuch as the engine might slip and break the other intermediate rod and do

incalculable damage. All side rods ahead of the intermediate on both sides would have to come down.

Question 82.—Should one of the forward tires, main tires, intermediate tires, back tires, or a trailer tire break, what must be done to bring the engine in?

Answer 82.—Run the wheel up on a wedge so as to clear the rail under all conditions; remove the oil cellar and fit a block in its place; then place another block between the bottom of the box and the pedestal binder. Also block under the equalizers nearest the disabled wheel to take the weight off the journal.

Question 83.—What is a good method of raising a wheel when jacks are not available?

Answer 83.—To run them up on frogs or wedges.

Question 84.—How can it be known whether the wedges are set up too tight, and the driving box sticks, and in what manner can they be pulled down?

Answer 84.—If the wedges are set up too tight, the boxes will heat, the engine will ride hard and have a rough, jerky up-and-down motion. Pull them down by the wedge bolts or if stuck tight, first jar the wheel by running over a nut on the rail.

Question 85.—What are some of the various causes for pounds?

Answer 85.—Wedges not properly adjusted, loose pedestal braces, lost motion between guides and crossheads, badly fitting driving brasses, improper keying of rod brasses, engine and rods out of tram, loose piston on rod or loose follower bolts.

Question 86.—How can a pound in driving box, wedges, or rod brasses be located?

Answer 86.—By placing the right main pin on the upper forward eighth, which brings the left main pin to the upper back eighth. Then by blocking the drivers, giving the cylinders a little steam and reversing the engine under pressure, both sides can be tested at the same time.

Question 87.—When should crossheads or guides be reported to be lined?

Answer 87.—When there is sufficient lost motion between crosshead and guides to cause a jumping motion when the pin is leaving either dead center and the crosshead is beginning the return stroke.

Question 88.—When should driving box wedges be reported to be lined?

Answer 88.—When the wedge has been forced up as high as it can go and lost motion appears between wedge and box. It should then be reported lined down.

Question 89.—When should rod brasses be reported to be filed? To be lined?

Answer 89.—When there is sufficient lost motion to cause pounding. When the key is down to a point where it cannot be forced down further to prevent the brass working in the strap.

Question 90.—When should lost motion between engine and tender be taken up?

Answer 90.—When there is ¼ inch or more lost motion between the engine and tender, causing an undue strain on the draw-bar by the forward and backward lurching of the engine while in motion, or the forward lurch in starting. It also causes a severe strain on the truss rods.

Question 91.—Describe the principle on which an injector works.

Answer 91.—The principle on which an injector works is a combination of forces, velocity and an induced current of water passing through suitably proportioned tubes, designated as steam nozzle, combining tube and delivery nozzle. Under a given pressure the velocity of escaping steam is much greater than that of water, which would be ejected were a hole opened in the boiler below the water line. The reduced orifice in the steam nozzle naturally increases the velocity of the escaping steam as it enters the combining tube where it entrains the feed water and condenses. As the escaping steam is being condensed it has lost none of its velocity except that due to friction of the pipes through which it passes, consequently it has a vastly greater penetrating force after condensation than the resisting force in the boiler. Leaving the combining tube the condensed steam and feed water now pass through the delivery nozzle into the branch pipe, where the ram-like force imparted to the water by the velocity of the escaping steam unseats the boiler check and permits the free flow of water to the boiler.

Question 92.—What is generally the cause of failure of the second injector and what should be done to obviate this failure?

Answer 92.—Infrequent use causes the various parts to corrode and the check to lime up and stick. Frequent use and a trial before starting on the trip will guard against such failures.

Question 93.—What are the advantages of the combination boiler check?

Answer 93.—It reduces the number of boiler check and injector failures.

Question 94.—If an injector stops working while on the road, what should be done?

Answer 94.—First ascertain the cause before applying the

remedy. It may be due to a disconnected and closed tank valve, clogged strainers, loose coupling in feed pipe which destroys the vacuum necessary to raise the water when starting a lifting injector, stuck check, etc.

Question 95.—How can a disconnected tank valve be opened without stopping?

Answer 95.—By closing the heater valve and forcing the steam from injector back into the tank to dislodge the valve.

Question 96.—How does the steam heat reducing valve control the pressure?

Answer 96.—By suitably adjusted springs and valves which restrict the steam passages in proportion to the amount of tension of the springs exerted upon the valves.

Question 97.—If steam heat gauge showed the required pressure and cars were not being heated properly, how should one proceed to locate the trouble?

Answer 97.—First make sure that the connections on the cars were all coupled and their respective valves opened to the rear end of train. If no steam appeared at rear car, examine each angle cock or valve, and, if they were open, look for the trouble at the regulator reducing valve.

Question 98.—What constitutes abuse of an engine?

Answer 98.—Slipping unnecessarily, improper care. working at a longer cut-off than necessary, pumping the water irregularly or in greater quantities than required.

Question 99.—How are accidents and breakdowns best prevented?

Answer 99.—By frequent and careful inspection before starting and during each trip.

Question 100.—What are the duties of an engineman when giving up his engine at the terminal?

Answer 100.—To thoroughly inspect the engine and report all defects in an intelligent manner.

Question 101.—In what manner should an engine be inspected on arrival at terminal?

Answer 101.—All running gear, frames, cylinders, saddles, bolts, wheels, fire-box, smoke arch and any other parts of the engine should be thoroughly examined and all defects correctly reported. No superficial examination is sufficient.

Question 102.—In reporting work on any wheel or truck on engine or tender, how should they be designated?

Answer 102.—It should be designated as engine truck, driver or tender truck wheel, giving the exact location and side. Some roads have adopted a method which prevents mistake, by numbering the wheels, beginning at the forward engine truck wheel and numbering it No. 1 and so on in consecutive numbers (not including the drivers) back to the

rear tank wheel. Also state whether right or left side, as R. No. 5 wheel.

Question 103.—In reporting work on an engine, is it sufficient to do it in a general way, such as saying "Injector won't work," "Lubricator won't work," "Pump won't work," "Engine don't steam," "Engine blows," etc.?

Answer 103.—No, the report should be explicit and assign a cause for every failure, so as to assist the shop force in remedying the defect.

SUPPLEMENTARY QUESTIONS AND ANSWERS. THIRD SERIES.

Question 1.—If an engine pounded when steam was shut off, what would it indicate?

Answer 1.—Flat drivers, loose follower bolt, main rod too short or too long.

Question 2.—What would you do in case of a broken trailer equalizer?

Answer 2.—Raise the back end of the engine and pry down the back end of main spring and block between hanger and frame; then pull down the cross equalizer on that side and block between the top of trailer, the equalizer and the frame to hold it there.

Question 3.—How would you block up for broken trailer tire?

Answer 3.—Run the trailer wheel up on a wedge a little higher than the thickness of tire, remove cover from trailer box, take out cellar and place block between bottom of journal and the box, place a block between bottom of box and pedestal and block cross the equalizer up in safety hanger or chain it to frame, place a tie or rail over deck of engine and chain trailer frame to tie, by the use of wedges the slack can be taken up in the chain.

Question 4.—How would you proceed to block up for a broken driver spring, spring hanger or equalizer on the Atlantic type (4-4-2 class) of engine? How for a broken trailer or hanger?

Answer 4.—For main spring, run main driver up on a wedge, block up back end of front equalizer and block back end of the back equalizer, run main driver down and run the front driver up, and put a block between the top of main driving box and the bottom of frame. If front driving spring, run main driver on wedge high enough to block between top of front driving box and bottom of frame, run main wheel down and front wheel up, this will free the spring rigging and permit blocking between front end of forward equalizer

and top of bottom frame. For trailer spring, raise frame and cross equalizer by placing a block between a tie and the bottom frame, and another block between the end of cross equalizer and tie, move engine on these blocks very carefully, put tie across top of trailer box in place of spring, and chain back end of tie to trailer frame, and front end to cross equalizer. For front trailer spring hanger, chain across equalizer to end of spring. If back hanger, block between water leg of fire-box and spring, raise engine up same as for broken spring.

Question 5.—What would you do in case of a loose or a lost cylinder key?

Answer 5.—Replace it with a suitable piece of iron, such as rod key, spike, etc.

Question 6.—Name the different parts of the engine that operate and control the valve motion.

Answer 6.—Reverse lever, reach rod, reversing arm, tumbling shaft, lifting arms, link hanger, link saddle pin and link, link block, link block pin, eccentrics, eccentric blade, rocker arms, valve rod and stem, valve yoke and valve.

Question 7.—How often does the ordinary locomotive exhaust steam during a revolution of the driving wheels, and at what point does the exhaust take place?

Answer 7.—The ordinary locomotive has four exhausts. When the right hand crosshead has moved back from the forward center to nearly the middle of the guides, the left engine is exhausting on its forward stroke. When the right hand crosshead reaches close to back end of guides, the right engine is exhausting on its backward stroke. When the cross-head returning reaches near the middle of the guides, the left engine is exhausting on backward stroke, and when the crosshead reaches close to the forward end of the guides, the right hand engine exhausts on the forward stroke.

Question 8.—What is a by-pass valve and what are its uses?

Answer 8.—The by-pass valve is a small valve similar to the check valve located on each end of the steam chest for the purpose of overcoming excessive compression. It is connected with the live steam side of the valve, and the steam port between the valve and the cylinder. It is held on its seat by boiler pressure and unseated when the compression in the cylinder is greater than the boiler pressure.

Question 9.—If a by-pass valve were broken, how would you test for it?

Answer 9.—A broken by-pass valve will cause a heavy blow at the stack when the exhaust port is open. Cover the exhaust port with the valve and if the blow ceases it indicates a by-pass valve blow.

Question 10.—What is a balance slide valve?

Answer 10.—It is a valve from which the steam chest pressure is withheld from part of the top of valve.

Question 11.—How is it balanced and why?

Answer 11.—The types of valves are the Richardson, American, and the piston valve. There is a face plate on the bottom side of the steam chest cover to both the American and Richardson valves, parallel with the top of valve and about 1-16 inch above it. The lower face planed smooth. The top edges of the Richardson balance valve have grooves in which the packing strips are set and are held up against the balance plate by springs. The difference between the American and the Richardson valves is in the balance. In the American valve, beveled rings are used instead of strips. The rings, which are made circular in form, have their inner face beveled to suit the bevel of the cone on top of the valve in which each ring is placed, and each ring is cut to make it flexible. The rings are turned up slightly smaller than the cone upon which they set, so, when they are forced to position by the steam chest cover, they are expanded slightly by the beveled face of the cone. When the steam is admitted to the chest it exerts a force on the entire outside face of the ring. This causes the ring to press more firmly against the cone and balance plate, which makes a steam tight joint. Piston valves are balanced by steam, it being nearly equal on all sides. Valves are balanced for the purpose of reducing friction between the rubbing surfaces.

Question 12.—What is the hole drilled in the top of the valve for?

Answer 12.—The hole drilled through the top of the valve into the exhaust cavity is for the purpose of relieving the top of the valve of any steam that might pass the packing rings or strips.

Question 13.—In the event of a valve, valve stem, or yoke becoming broken inside the steam chest, how can the breakage be located?

Answer 13.—Place engine at half stroke, admit a little steam to cylinder; then move the reverse lever from full forward to full back gear, and if steam will escape alternately from both cylinder cocks, would conclude that the defects were in the opposite chest and then try that side.

Question 14.—After having determined on which side the defect is, how would you put the engine in safe condition?

Answer 14.—For broken valve, if I could cover one admission port and exhaust port, would disconnect the valve stem and clamp centrally on seat. Disconnect the main rod and block the crosshead to opposite end of guides. If exhaust and admission ports cannot be covered, take up the chest

cover and block the supply ports. If on heavy power, take down the main rod and prepare to be towed in as some of the pieces might work into the cylinder and do further damage.

Question 15.—If on a piston valve engine?

Answer 15.—If stem or yoke is broken, and chest will keep valve from going too far ahead, it will cover front admission port and exhaust port; disconnect valve stem and shove it up against valve and clamp it there, take down main rod, block crosshead to opposite end of guides to which admission port is open. If valve goes too far ahead, and there is a relief valve in front of the chest, take it out and shove the valve back centrally on its seat; fit a block in, to hold from going ahead, and clamp the stem up against it to keep it from going back. If piston valve, take off head to chest, and if the valve is not broken too badly place it centrally on its seat, and block from the head to the valve to keep it from going ahead; disconnect the valve stem and clamp it against the valve to keep it from going back. If the valve is broken so badly that you cannot keep steam from the exhaust, take down the main rod and prepare to be towed in. If stem on piston valve, plumb the rocker arm and disconnect valve stem and clamp it, then shove valve back against the stem and block between valve and head.

Question 16.—If a locomotive is disabled on one side, and the main rod and the piston are left up, and the good engine stops on center, how can you get the locomotive started?

Answer 16.—Move the valve on the disabled side by hand, giving the engine enough steam to move her off center.

Question 17.—How can you distinguish between a valve, cylinder packing, or valve strip blow; and how locate which side it is on?

Answer 17.—A valve blow is continuous, cylinder packing will blow the hardest at the beginning of the stroke. Place valve centrally on its seat, giving engine steam, and if it appears at either cylinder cock, it is a valve blow. For cylinder packing blow, place lever in full gear, engine on the quarter and give engine steam; if it appears at the opposite cylinder cock, it indicates cylinder packing blow. A valve strip is a continuous blow, sounding as though the blower was on quite strong. The side it is on can be located on engines that have pipes or drain cocks tapped onto the exhaust cavity under the saddle by giving engine a little steam when standing, and steam will blow out of pipe on whichever side leak is. This kind of blow can also be located by the increased friction, which will cause the valve stem on that side to jerk when in motion; or it may be located by placing the crank pins on the quarter alternately and handling

the reverse lever under steam pressure; the blow will be on the side which handles the hardest.

Question 18.—What would you do if the packing blew out of the throttle stuffing box?

Answer 18.—Reduce steam pressure and repack the stuffing box with candle wicking, bell cord or anything suitable to stop the flow of steam and water.

Question 19.—Explain why moving the reverse lever from one end of the quadrant to the other reverses the motion of the engine.

Answer 19.—With the reverse lever in forward gear, the link is below the center line of motion and the go-ahead eccentric controls it; with the lever in back gear, the link is raised above the center line of motion and the back-up eccentric controls it.

Question 20.—What is the throw of an eccentric?

Answer 20.—That part which is out of center with the axle to which it is attached.

Question 21.—With an engine equipped with grease in the driving box cellars, how would you know that there was sufficient grease in the cellar to make the trip? If it needed packing on the road, how would you proceed to pack it?

Answer 21.—By the indicators in the bottom of the cellar. By pulling down on the indicators which compresses the spring, remove plate on side of the cellar and refill with grease, being careful to get it between the perforated plates and the plate on top of spring.

Question 22.—Explain how you would adjust the grease cups to get the best results, and effect the greatest economy in the use of grease.

Answer 22.—Grease cups should be filled to within one-half inch of the top; care should be exercised in screwing down the plug not to force too much grease onto the pin. A good practice is to first try the rod on the pin; if it move freely, screw the plug down until you feel the rod commence to move hard; you then have sufficient grease on the pin to run over the division.

Question 23.—In reporting work on any wheel or truck of engine or tank, how should you designate by number which one is meant?

Answer 23.—Beginning with the first wheel behind the pilot as No. 1 and following to the rear wheel of tank, not including the drivers, designate them in their numerical order, and using the letters "R" and "L" to indicate the side of engine on which they are.

Question 24.—What would be the result if guides and crossheads are not in line?

Answer 24.—Danger of guides heating and cutting, also

breaking off of guide lugs on back cylinder heads, cylinder wearing out of round and main rod brasses heating.

Question 25.—Why should the sand from both sand pipes strike the rail?

Answer 25.—To avoid straining the engine on one side more than on the other and to prevent uneven wear of tires.

Question 26.—What is superheated steam?

Answer 26.—Superheated steam is steam heated to a higher temperature than the water from which it is generated.

Question 27.—How is it superheated and what benefits are derived from it?

Answer 27.—It is superheated by passing through a system of tubes which are exposed to the fire and the hot gases in the front end and give it more expansive power.

Question 28.—How is the boiler of the locomotive connected to the frames?

Answer 28.—The front end of the boiler and the frames are securely fastened to the cylinder saddles, again about midway back the boiler is secured to the frames by belly braces to prevent side motion but not expansion, and at the fire-box side motion is also prevented. The fire-box end of the boiler is carried on the frames by expansion plates or by expansion hangers as the case may be, but is free to move backward and forward on the frames as expansion and contraction take place. If the frames were as hot under steam pressure as is the boiler, the fire-box end of the boiler could be rigidly attached to the frames.

Question 29.—With an ordinary sized locomotive boiler how much will the fire-box move on the frames?

Answer 29.—About three-eighths to one-half of an inch.

Question 30.—Are the cylinders fastened rigidly to the frames?

Answer 30.—Yes; in fact, they are generally a part of the saddle castings.

Question 31.—Are the driving wheel axles secured rigidly to the frames?

Answer 31.—No; the driving boxes riding these axles can move up and down to permit the wheels to conform to the inequalities of the track, but are rigidly held against forward and back motion by shoes and wedges bearing against the jaws of the frames.

Question 32.—Are the frames supported directly by the driving boxes?

Answer 32.—No. The driving boxes support springs the ends of which are fastened to the frames directly or through equalizers.

Question 33.—What is the purpose of the equalizers?

Answer 33.—To always retain same weight upon each

driving box even when one wheel strikes a high or low spot in the track. They make an engine ride more easily on rough track.

Question 34.—How hot should you have engine oil to oil around with in winter?

Answer 34.—No hotter than blood heat—98°—and if oil is then too thick to run well, thin it down with kerosene.

Question 35.—What is the harm of thinning it by heating it very hot?

Answer 35.—As soon as it strikes the cold surfaces it will thicken and not feed properly to the bearings.

Question 36.—When wedge bolts are broken so that you have to slip in an extra nut between the wedge and the binder, or splice the bolt by running half of the nut on each side, should the wedge be set up tight?

Answer 36.—It should be left down a trifle, for it is better to have the box pound a little than to run the risk of having the wedge stick on the box and get pulled up and stick fast with no means of pulling it down.

Question 37.—What trouble is likely with broken wedge bolts?

Answer 37.—Wedge is likely to stick to the box on rough track and be pulled up so high as to stick and cause the box to run hot.

Question 38.—What would be the effect of broken cylinder packing?

Answer 38.—Steam when admitted to one end of the cylinder would blow by the piston and show at the other end of the cylinder, if the cylinder cocks are opened.

Question 39.—What is meant by "snap ring" packing?

Answer 39.—A circular ring usually of cast iron, and cut at one point. This ring is opened up and snapped over a solid piston or applied each side of the bullring in a made-up piston. Such rings are made from one-eighth to one-fourth of an inch larger outside diameter than the cylinder and a piece cut out so that the ends will just touch when compressed in the cylinder.

Question 40.—When such rings are first applied to a cylinder why do they often permit steam to blow by for a short time?

Answer 40.—Because they generally have to wear slightly before they conform perfectly to the shape of the cylinder.

Question 41.—If a ring becomes worn until it has a smaller outside diameter than that of the cylinder what will be the result?

Answer 41.—It will allow steam to blow by the piston, but not always at high steam pressures. The engine will be wasteful of steam, and yet if tried under high steam pressure

may set the packing out sufficiently to prevent a blow. With such an engine under short cut off, when the steam had expanded somewhat in the cylinder the pressure would not hold the packing rings in place and steam would blow by. Test such an engine under low steam pressure.

Question 42.—What would be the "symptoms" in the above case?

Answer 42.—The engine may have made several thousand miles since shopping and used steam economically and then lose her "snap" and apparently through at early cut-off and high speed. By dropping the lever, thus increasing the pressure behind the snap rings during the entire stroke, the blow ceases.

Question 43.—What will be the result if brasses are not kept keyed up properly?

Answer 43.—They will wear rapidly and often break themselves. Any serious pound about a locomotive is liable to loosen various parts of the engine.

Question 44.—Is it safe to key up side rods with the wedges down or loose?

Answer 44.—It is not, the wedges should be first set up or you are likely to key the rods out of tram.

Question 45.—Would you set up wedges as tight on a passenger engine as on a freight engine?

Answer 45.—No. On a passenger engine most men prefer to set them up a little at a time.

Question 46.—Would the condition of the track make any difference?

Answer 46.—Yes, on rough track wedges are more likely to stick if set up tight.

Question 47.—What will be the result if an engine is out of tram?

Answer 47.—She will ride hard, having a hitch every time the rods pass the center, the pins are likely to heat and considerable of the engine's power be wasted.

Question 48.—If you felt a pound after keying up a main rod what is likely the cause?

Answer 48.—Probably the main rod is too long and allows the piston to strike the front cylinder head. Such a pound is most noticeable when steam is shut off and the engine drifting as there is then less compression to counteract this.

Question 49.—How could you shorten a main rod?

Answer 49.—By changing a thin liner from the end of the rod to the back of the strap. Such work is usually done at round-houses by the machinists and repairmen.

Question 50.—Will a loose pedestal brace or bolt cause an engine to pound?

Answer 50.—It will, and if not attended to is likely to break the frame.

Question 51.—With a follower bolt loose what will be the effect?

Answer 51.—It will cause a pound at the forward end of the stroke when it strikes the front cylinder head. Shutting off steam, as in the case of too long a main rod, will increase the pound.

Question 52.—Is it safe to run with a loose follower bolt?

Answer 52.—It is not, as it is likely to come out, knock out the front cylinder head and perhaps break the piston and cylinder. Work a little steam and try to get to the next siding if the pound does not increase, and there take off the cylinder head and remove the bolt unless you have a good wrench with which to tighten it.

Question 53.—If for any reason you should have occasion to open the front end door, how would you proceed to tighten up the clamps?

Answer 53.—Close the door, tighten the bottom clamp first, then the clamps on either side; the top one last, so that if the door or ring is warped any leakage will be at the top of door and though injurious in a degree to the draft of the engine, still it will not cause the cinders in the front end to burn.

Question 54.—What is wrong when the throttle becomes disconnected and what could you do if on a branch line a long distance from the shops?

Answer 54.—One of the pins has probably come out of or broken from the bell-crank or the stem, or the throttle valve rod is broken. Blow all the steam off the boiler, take up dome cap, discover the defects, send it in for repairs or better still fix it yourself at the nearest blacksmith shop. In early days of railroads in this country, enginemen frequently did such extensive repairs as this themselves.

Question 55.—Will any defects in the front end cause an engine to sound out of square?

Answer 55.—Yes. Exhaust pipe joint blown out on one side or one tip of a double nozzle blown out. Sometimes a worn out petticoat will also cause this.

Question 56.—What term is used where an engine has no lead?

Answer 56.—The engine is called "blind."

Question 57.—What will be the effect if the eccentric has slipped toward the crank pin on that side?

Answer 57.—The amount of lead will be increased, and hence steam admitted to the cylinder considerably before the piston gets to the end of its stroke.

Question 58.—What will be the effect if the eccentric has slipped away from the crank pin on that side?

Answer 58.—The lead will be taken away, and if slipped much, the piston may have started on its return stroke before steam is admitted.

Question 59.—How can you tell which is the go-ahead and which is the back-up eccentric?

Answer 59.—The go-ahead eccentric is attached to the top of the link, the back-up to the bottom, on all ordinary locomotives.

Question 60.—What other aid have you to find a slipped eccentric or rod after you have stopped?

Answer 60.—If I found one eccentric hot or the set screws loose, would consider that first.

Question 61.—If only one eccentric has slipped, how can you tell what its position should be in reference to the other eccentric?

Answer 61.—The go-ahead eccentric on one side should be exactly ninety degrees or at right angle to the other go-ahead eccentric, and the relative position of the back-up eccentric are the same. Whichever crank pin of the engine leads, the eccentric on that side leads the opposite one. This answer is true for all kinds of valve motion.

Question 62.—How can you set an eccentric on the road by means other than its relative position to the other, or to the crank pin?

Answer 62.—Place the engine on either center on the defective side. Put the lever in full gear for the good cccentric and with a knife mark the valve stem close to the gland. Now place the lever in equally full gear (gauging by the link block) in the opposite direction and then move the loose eccentric around on the shaft until the strap on the valve stem comes even with the gland again. Another way is to put the engine on center on that side, put the reverse lever in full gear for that motion, set the brake and block wheels securely; have the fireman open the throttle slightly while you move the slipped eccentric in the opposite direction from the one next to it until steam shows at the cylinder cocks at the end of the cylinder wherein the piston lies.

Question 63.—Why are slipped eccentrics of less occurrence now than in former years?

Answer 63.—Now they are most all keyed on, the set screws only keeping them from slipping endwise on the axle; formerly the set screws were depended upon entirely to hold them in place.

Question 64.—On which center would you place an engine to set an eccentric?

Answer 64.—On whichever center enabled me to more easily get at the eccentric and set screw.

Question 65.—In case of a very hot eccentric, would you put water on it?

Answer 65.—You should not, as it would be likely to break or warp the strap.

Question 66.—What usually causes the eccentrics or blades to slip?

Answer 66.—It may be any of several causes: set screws loose, hot eccentrics, or some one tightening up set screws when the bolts holding the two eccentric parts together are loose. In this latter case the cam would be jacked out tight against the strap.

Question 67.—What would you do for a hot eccentric on the road?

Answer 67.—Oil it well, using valve oil if very hot; see that the strap was not tight on the cam and if it were, loosen the strap bolts and put in one or more tin liners between the two halves of the strap on both sides, then tighten bolts.

Question 68.—How do some roads secure blades in straps so as to prevent their slipping?

Answer 68.—Some roads slot all holes and after the blades are set and adjusted, they run soft metal into the slots beside each bolt. Other roads often slot one hole in each blade and after setting valves drill the remaining holes to correspond with those in the strap without slotting them.

Question 69.—What would you do to "disconnect" an engine on one side as the term is generally applied?

Answer 69.—Place the valve in the center to cover the steam ports and clamp or bind the stem to hold it there, take down the main rod and block the crosshead securely (preferably at the back end of stroke). If any side rods are broken, remove the same ones on the opposite side.

Question 70.—On very heavy locomotives is there any way to avoid taking down the main rod?

Answer 70.—Yes. If but a short distance to go, block the valve just enough ahead of the center to admit a little steam to the back end of the cylinder, and if the engine does not have by-pass valves take out the back cylinder cock or block it open and loosen the front cylinder head.

Question 71.—For what causes would you disconnect as stated?

Answer 71.—For broken front cylinder head; valve, valve seat, valve stem or rod broken; broken rocker arm, eccentric, strap, blade, link or parts of link.

Question 72.—If you take down one eccentric blade what should you do to prevent the link turning over, binding, or striking the engine truck frame?

Answer 72.—Tie the top of the link to the hanger or

otherwise fasten it but not too tightly. It is generally better to take off both eccentric and straps on that side if you have to take down one.

Question 73.—Can an engine be run ahead with a back-up eccentric strap or blade taken down?

Answer 73.—Yes. For if kept in full gear the link block will get all its motion from the go-ahead blade. The reverse condition is true with regard to a broken go-ahead eccentric. This practice should not be followed except in moving an engine to the nearest siding before disconnecting the valve stem.

Question 74.—What would you do if the whistle or pop valve should blow out?

Answer 74.—Plug the opening with a piece of soft wood and tie it down if possible.

Question 75.—If stuck in a snow bank, how would you keep water in the tank?

Answer 75.—If necessary, shovel snow in the tank and melt it with the heater.

Question 76.—When an engine is standing and the throttle is closed, what will cause steam to escape from the cylinder cocks?

Answer 76.—If the lubricator was shut off so that no steam could come through the oil pipes, it would indicate either a leaky throttle or a leaky dry pipe.

Question 77.—How can you distinguish a leaky dry pipe from a leaky throttle valve?

Answer 77.—With a dry pipe leaking, if there is enough water in the boiler to cover it, the escape from the cylinder cocks will be nearly all water. With the throttle leaking, it will show dry steam.

Question 78.—Is a leaky throttle dangerous?

Answer 78.—It is, and should be reported and ground in as soon as possible; in the meantime leave the cylinder cocks open when standing and block the wheels well before going under the engine or leaving her.

Question 79.—Then to test a leaky dry pipe should there be more water than usual in the boiler?

Answer 79.—Yes. Some boilers have to be filled above the top of the water glass in order to entirely submerge the dry pipe should the latter leak at its top side.

Question 80.—Name the various causes for an engine pounding.

Answer 80.—Loose or worn rod brasses or worn pins; loose or worn wedges or binders; driving box brasses worn or loose in the boxes; piston rod loose in its crosshead; worn guides or crosshead; loose gibs in crosshead; loose cylinders or deck; flat driving wheels; main rod too short or

too long or loose follower bolts; badly worn expansion pads on the sides of the fire-box; a broken frame; pedestal bolts loose.

Question 81.—Name the various causes for a blow in an engine.

Answer 81.—Valves, valve seats or cylinder cut; balance strips broken, stuck down or broken springs under strips; balance plates too high above the valve; broken or worn packing rings in piston valves; broken or worn cylinder packing rings or rings turned around so that their openings come opposite each other at the top of piston; broken valves or valve seats, and sometimes a blow under a false valve seat.

Question 82.—How would you test for a blow in the balance strips or valves?

Answer 82.—Place the engine on the center (top preferred), the reverse lever in center notch, and open the throttle and cylinder cocks. If very little steam shows at either cylinder cock on that side, defective balance strip will still cause a blow through the hole in top of valve to the exhaust cavity and out of the stack. By moving the lever a notch or two each side of center, just enough to connect the exhaust cavity with either cylinder port, a slight escape of steam will appear at the corresponding cylinder cock. Test the opposite side of the engine in the same way.

Question 83.—Why are all large valves balanced?

Answer 83.—To reduce the frictional resistance and also the wear between the valves and their seats.

Question 84.—What provision is made for the escape of any steam that may leak to the inside of the balance strips or rings?

Answer 84.—A hole is drilled through the top of the valve into the exhaust cavity.

Question 85.—If this hole were plugged, what would be the effect?

Answer 85.—The valve would be unbalanced and like an ordinary slide valve.

Question 86.—What advantages are claimed for piston valves?

Answer 86.—Greater port areas and more evenly balanced valves.

Question 87.—In what way have some slide valves been given greater port areas without increasing the size of the valve?

Answer 87.—By supplemental ports. The Allen valve being the most common.

Question 88.—What is meant by the valve being "line and line" inside?

Answer 88.—With the valve on the center of its seat, that

the inside edges of the cylinder ports are in line with the edges of the exhaust cavity.

Question 89.—What is the advantage of working steam expansively?

Answer 89.—To effect an economy of steam which means economy of fuel. The following tables from a well known authority will clearly indicate the reasons for this economy if the student will compare the total heat with the amount of work done in each case:

Cut-off, Inches.	Initial Steam Pressure.	Ratio of Expansion.	Average Cylinder Pressure for Entire Stroke.	Ft.—Lbs. Work done.	Heat contained in steam used.	Pounds of water used in doing the work.
8	200	3	125	31,800	618	.52
24	140	1	125	31,800	1299	1.12

EXPLANATION.—The above table shows that 200 pounds of steam with a cut-off of 8 inches (⅓ stroke) gives the same average cylinder pressure for the whole stroke and does the same amount of work but with less than one-half the heat and the water that a full 24 inch stroke with 140 pounds of steam pressure will give.

Pounds of steam used.	Initial Steam Pressure	Cut off (with 24-in stroke.	Ratio of Expansion.	Pressure in Cylinder at end of stroke.	Average Cylinder Pressure for Entire stroke.	Ft.—Lbs. Work done.	Total heat at 200 lbs. pressure.	Total heat at final pressure.	Heat saved.	Comparison of work done.
1.57	200	24	1	200	185	47,064	1888	1888	0	1.00
1.57	200	12	2	110	155	78,864	1888	1807	26	1.67
1.57	200	8	3	66	135	95,400	1888	1798	40	2.02
1.57	200	6	4	50	105	106,848	1888	1775	58	2.27

EXPLANATION.—From the above table the last column shows the relative advantage of the shorter cut-offs over the full stroke—the first line of table.

Question 90.—Cannot economy be effected with cut-offs still shorter than six inches?

Answer 90.—Not with our modern high pressure boilers, for with still greater expansion the final temperature in the cylinder is so low that great condensation takes place in the cylinders.

Question 91.—Is there any other bad result from too short a cut-off?

Answer 91.—Yes. Flat spots are made in driving wheel tires by such practice. Some roads go so far as to block quadrants of locomotives so that the reverse lever will not

latch anywhere between the center and the six-inch cut-off notch.

Question 92.—What effect has it on the valve to lengthen or to shorten the blades?

Answer 92.—It equalizes the travel with reference to the center of the valve seat but it does not alter the total lap or lead of the valve—whatever amount it takes from one end of the valve is added to other end, that is to say, if the lead is one-sixteenth inch at one end and line and line at the other end, if you lengthen or shorten the eccentric blade (according as the rocker arms are arranged), the lead can be divided so as to be one thirty-second of an inch at each end.

Question 93.—What is the usual cause for cracked or broken steam chests?

Answer 93.—Reversing an engine when throttle is shut off and the engine is running at high speed.

Question 94.—Why is this likely to rupture a steam chest?

Answer 94.—The cylinders of a reversed engine draw air and gases from the front end and force them into the steam chests, steam pipes, dry pipe and stand pipe, and as the throttle is closed there is no escape. The more modern locomotives have steam chest relief valves in order to relieve such excessive pressure.

Question 95.—What should be done if an engine is reversed at high speed?

Answer 95.—Open the throttle which will allow the air to pass into the boiler and be relieved at the safety valves.

Question 96.—If the reverse lever should get caught and bound tightly at a short point of cut-off (due to broken driving spring, spring hanger, or equalizer) what would you do?

Answer 96.—Try to pinch the light engine ahead sufficiently to take steam, then block up for broken parts. If necessary to get the train off the main track quickly, you can disconnect the reach rod from the tumbling shaft lever and let the links drop down onto the link blocks so that the engine will be in full forward gear. If you have any distance to go get the engine blocked for the broken parts, free the reach rod and reconnect the tumbling-shaft arm.

Question 97.—How could an engine be moved if the engine truck was demolished?

Answer 97.—Jack up the front end of engine and block up on top of the forward driving boxes and run very slowly to prevent these forward driving boxes from running hot.

Question 98.—At what points of the frame is the weight of a locomotive carried?

Answer 98.—At the equalizer stands, front and back hangers and at the engine truck center casting.

Question 99.—In blocking the crosshead of a locomotive,

subsequent to disconnecting, does it make any difference whether it is blocked ahead or back?

Answer 99.—Yes. With engines having their forward driver opposite the guides the crossheads must be blocked full ahead or the forward crank pin may strike the wrist pin.

Question 100.—In case it became necessary to remove the side rods on such an engine can the engine be run safely?

Answer 100.—Not always. It should be definitely determined that the crosshead pin or key and forward crank pin cannot interfere with each other.

Question 101.—In taking off a main rod how are the side rods to be held on the main pin?

Answer 101.—By a wood or iron collar to clamp on the outer end of pin, thus taking the place of the main rod. If there is no such collar on hand, saw pieces of wood to fit the pin lengthwise and tie them securely around the pin.

Question 102.—With a broken frame jaw, what would you do?

Answer 102.—I would try to take my train in.

Question 103.—If an engine with a broken frame is to be towed, how should it be done?

Answer 103.—Such an engine should not be towed either at the front or rear of a long heavy train as the shocks and strains on the frame are too severe in such a train.

Question 104.—What would you do if the spring of the steam chest relief valve were broken so that the steam blew badly?

Answer 104.—Screw down on the spring, or block the valve closed, and report it at the end of the run.

Question 105.—How does the rod grease cup work?

Answer 105.—By means of a screw plug or piston, the grease in the cup is forced down through the small oil hole onto the pin.

Question 106.—If you put water on a pin using grease what is the result?

Answer 106.—It forms soap of the grease and causes it to rapidly disappear from the cup.

Question 107.—How would you try to get a leaky or stuck open boiler check to close?

Answer 107.—Tap it gently on the flange of check, open the "frost" cock and pour cold water over check.

Question 108.—What usual precautions must be taken in cold weather?

Answer 108.—Trains must be started and stopped very carefully to prevent breaking of draft gear or sliding wheels. If any water or steam is leaking from the tank, be sure the wheels are turning when you start as a brake shoe is very likely to freeze to the wheels and slide them

Question 109.—Where is the frost cock?

Answer 109.—It is located on the discharge or "branch" pipes on either side and at the lowest point, usually a few feet from the boiler check and nearly above the guides.

Question 110.—What damage can water do if it escapes from these frost cocks?

Answer 110.—It may freeze on the guides and blow all over the links, eccentrics and running gear of the engine; hence a pipe should lead from these cocks to a point near the ground and this pipe always be seen to be open and not frozen up.

Question 111.—What would result from a too free use of the heater?

Answer 111.—The feed pipe in the tank would become too hot to be taken up by the injector and cause trouble from failure of the injectors.

Question 112.—What else should be watched in cold weather?

Answer 112.—The air pump, steam bellringer, and electric headlight engine (if you have one). Do not allow any of them to be shut off for any considerable length of time, but keep a little steam flowing through them even though their services are not required. Before taking an engine out of the house in very cold weather, go to the back end of the tank and blow out the rear air brake, air signal, and steam heat hose to be sure they are open, as these are near the round-house doors and sometimes freeze up.

Question 113.—In cold weather why are leaks in the mud ring much worse than at other times?

Answer 113.—Because this water will soon freeze up the ash pan and the dampers, and shut off all draft. A steam hose with a connection to the syphon cock on top of the dome is carried on many engines in very cold climates. With this hose ice and snow may be melted from the machinery, ash pan and dampers, when necessary.

Question 114.—At what time of year do the most hot boxes occur?

Answer 114.—During the coldest portion of the winter.

Question 115.—Why is this?

Answer 115.—Because then lubrication is the poorest, ice and water get on top of driving boxes and prevent oil from feeding, and the waste in cellars gets frozen stiff so it does not bear against the journal. In very cold weather clean off and put new waste on top of the driving boxes frequently.

Question 116.—How are many locomotives equipped for cooling hot bearings?

Answer 116.—By water pipes leading to the cellars of every journal on the engine and also the pins.

Question 117.—When would you turn water onto a hot bearing?

Answer 117.—Only when, to the best of my judgment, a failure to do so would result in serious delay to my train or other important trains. It is best to endeavor to cool off the bearing by better lubrication than to use water which washes off the oil.

Question 118.—Why is it thought best to put the water pipes in the cellars instead of on top of the bearings?

Answer 118.—Because it still allows some oil to be fed down from the top, instead of washing it all off.

Question 119.—What kind of waste is best for use on cellar-packed journals, such as engine trucks, tank trucks, trailer wheel boxes, and driving box journals?

Answer 119.—Good long fibre cotton waste, having been saturated in oil for not less than 24 hours.

Question 120.—Why is cotton waste better than wool waste for such purposes?

Answer 120.—Because it has much better capillary attraction and feeds oil up much better.

Question 121.—How can you prove this?

Answer 121.—By suspending a long cotton cloth and a woolen one with their lower ends in water or oil and then note how much more rapidly the water or oil feeds up the former.

Question 122.—Such being the case, why do so many roads use wool waste in all engine truck and driving box cellars?

Answer 122.—Because it has more "spring" to it and hence does not pack down and away from the journal so quickly.

Question 123.—What special forms of cotton packing are made with the intent of increasing its spring?

Answer 123.—Various forms of woven and twisted fibre and an ordinary cotton waste with a fine steel shaving running through it to give it spring.

Question 124.—If a tender or engine truck box ran hot in spite of your best efforts, what would you do?

Answer 124.—If I had an extra brass on the engine to fit this, jack up the box and remove the brass. In the case of an engine truck this would cause too long a delay to an important train, hence the use of the water pipe on many locomotives.

Question 125.—If your rod brasses were babbitted and you noticed a pin getting hot enough to melt the babbitt and was throwing it out, what would you do?

Answer 125.—I would not stop until all babbitt was thrown out and hence the oil hole open. Should I stop at once the babbitt would likely close the hole in the strap and oil cup and cause a great deal of trouble in removing it.

Question 126.—In what does the abuse of an engine consist?

Answer 126.—Not taking proper care of or reporting the work to be done on an engine, slipping an engine unnecessarily and catching the engine on sand, reversing an engine while moving, working the engine harder than necessary, pulling or tearing holes in the fire, irregular boiler feeding, and poor firing.

Question 127.—Should either injector be used to the exclusion of the other?

Answer 127.—No. Non-use is one of the most frequent of injector troubles. Many reliable enginemen think it an excellent plan to use, say, the right injector going over the road in one direction and the opposite injector on the return trip.

Question 128.—Why cannot this be made a good rule to follow on all engines?

Answer 128.—Because many locomotives have a size larger injector on one side than on the other.

Question 129.—If an injector is continually used for a heater, what will likely follow?

Answer 129.—The hose strainer gets coated with lime; the boiler check and adjustable parts of injector become covered with scale and stuck.

Question 130.—How many miles should an engine run to the pint of lubricating oil?

Answer 130.—That depends upon the size of the locomotive and the work it has to do. Most roads feel that 150 miles for valve oil and 50 miles for engine oil, per pint, is a record to be striven for.

Question 131.—How many drops are there in a pint of valve oil?

Answer 131.—The following table from a well known authority will show, and also give further data to determine the setting of injector feeds:

Capacity of Lubricators.	Total No. of drops contained in lubricator.	Number of drops for each cylinder per minute.	Hours consumed in feeding out a lubricator.	Total miles run on a basis of		Number of miles run to one pint of oil on a basis of	
				Passenger 30 miles per hour.	Freight 18 miles per hour	Passenger 30 miles per hour.	Freight 18 miles per hour.
2 pints.....	13,200	5 drops.....	22 hours..	660	396	330	198
3 pints.....	19,800	5 drops.....	33 hours..	990	595	330	198
Triple feed.. 3 pints.....	19,800	5 drops and 1 drop for air pump	30 hours..	900	510	300	180

Question 132.—What harm is done an engine by sand pipes being stopped up on one side?

Answer 132.—It produces a great strain, often breaking crank pins or rods and also causes an uneven wear of tires.

Question 133.—In what ways are automatic bell-ringers operated?

Answer 133.—By air or by steam pressure.

Question 134.—Which is the better and more generally used?

Answer 134.—Air, because it does not condense or freeze and its exhaust does not obscure the vision, as does condensed steam.

Question 135.—Particularly in the western parts of the United States, what causes the greatest trouble with locomotives?

Answer 135.—Poor water. It has been estimated that the poor water on western railroads necessitates an additional expense of about $750 a year for each locomotive in service.

Question 136.—What is meant by poor water?

Answer 136.—Generally speaking, "hard" water, that is, water having incrustating matter which causes foaming and sometimes acids which eat into the flues and boiler sheets.

Question 137.—If these solids are in solution why should they cause trouble in a locomotive boiler?

Answer 137.—Because when such large quantities of water are evaporated, the solid matter remains as a sediment, some portions of which form a coating over the flues and sheets thus preventing the water from coming in direct contact with the iron. The result is the iron becomes overheated and cracks, and with all its overheating less heat is imparted to the water in the boiler.

Question 138.—How much of these incrustating solids are contained in a given quantity of hard water?

Answer 138.—This varies greatly, from two to twenty pounds per 1,000 gallons.

Question 139.—How can much of this solid matter be gotten rid of after the water is evaporated?

Answer 139.—By blowing it out of the boiler.

Question 140.—How is this done?

Answer 140.—One or more blow off cocks are placed in various parts of the boiler—generally just above the mud ring, as there is where the most of the sediment settles.

Question 141.—How are these blow off cocks operated?

Answer 141.—By hand, or by pneumatic (or steam) pistons attached to the valves.

Question 142.—What effort is made by many railroads to overcome the bad effects of "hard" water?

Answer 142.—Some kind of boiler compound, such as soda-

ash, is put in the locomotive tank each trip. This forms a chemical action with some of the incrustating solids causing less incrustation, but leaving more sediment which must be blown out or will cause foaming in boilers.

Question 143.—What other means are railroads adopting?

Answer 143.—The chemical treatment of water in large settling tanks located at the various water stations where poor water is had. The solids are allowed to settle and the clear and almost soft water above is pumped into the water tanks and then used for locomotives.

Question 144.—If your engine should get off the track with one or more wheels, how would you proceed to get it on again?

Answer 144.—Conditions vary in every case. If the wheels are close to the rails, block up with oak blocks or wedges to a pair of good wrecking frogs (car replacers) and run the engine up on the track. It is a general rule to follow, that an engine will go on best and most easily by retracing the path whence it got off.

Question 145.—In case of a derailment what should you do first?

Answer 145.—Look the situation over carefully, see how the engine stands, that the water and fire in the boiler are safe; if the wreck is serious telegraph for another engine and wrecking outfit; if not so serious, wire for another engine to help pull you on; if you think it possible to move the engine alone, put down some blocks and try it before sending for help.

Question 146.—If the rails are spread to what gauge should they be spiked?

Answer 146.—Four feet eight and one-half inches on straight track and about one-half an inch more on sharp curves.

Question 147.—After your engine is back on the track again, what would you look for?

Answer 147.—Broken driving box cellars, bent or sprung rods or crank pins, broken draw castings or draw bars, broken brake rigging, sprung axle or journal.

Question 148.—Suppose a driving box cellar or its lugs were broken what would you do?

Answer 148.—I would make one of wood or in some way block on top of the binder sufficiently to hold the packing against the journal.

Question 149.—Why is it not safe to run an engine with a sharp flange?

Answer 149.—Because it is very likely to catch a switch point or a frog and cause a derailment, or the flange may break and cause a bad wreck.

Question 150.—Are there any locomotives that cannot run under their own steam with their side rods off?

Answer 150.—Yes, because of the extreme effort of modern builders to get long main rods and short straight eccentric blades. In order to do this the eccentrics are not placed upon the main driving wheel axle but upon one of the driving wheel axles ahead thereof. Hence, with the side rods off the least slip of the main drivers would throw them out of tram with the driving wheel carrying the eccentrics, consequently such an engine would have to be towed in. This construction is becoming quite common for switching locomotives, which class of power is, of course, seldom out on the road where delays from breakdowns are most serious.

Question 151.—If you had, say, a disabled cylinder and had no drift to disconnect valve stem, what would you do?

Answer 151.—Take out top rocker arm pin, pull the valve rod an inch out of line with the top rocker arm and brace there securely by a notched-end stick. Disconnect the main rod and clamp the valve in center; and block crosshead, of course.

Question 152.—On very large locomotives with heavy rods is there any way to avoid taking down and loading up the main rod?

Answer 152.—Yes. If the main rod goes through a yoke at back of guides, take down the back end of main rod and block the crosshead ahead, letting the main rod rest in the bottom of this yoke.

Question 153.—In running an engine on one side how can you almost entirely prevent stopping on the dead center?

Answer 153.—By stopping the engine with the reverse lever, giving her a little steam. When the engine has stopped and before she starts to back up, set the brake hard, close the throttle and open the cylinder cocks.

Question 154.—Why will this be quite certain to keep the engine off the dead center?

Answer 154.—Because the power to stop the engine being entirely in the cylinder of the good side, the greater power is on the quarter and is nothing on the dead center to cause the engine to stop at that point.

Question 155.—In blocking a crosshead should you place it as far forward or as far back as it is possible to do?

Answer 155.—No. Put a small block at the front or back end of crosshead, as the case may be, in order to prevent all possibility of the cylinder packing rings dropping into the counterbore.

Question 156.—What harm would that do?

Answer 156.—It might necessitate the removal of the

adjacent cylinder head; and if a back one it is a long, expensive job.

Question 157.—How would you arrange to run a mogul or consolidation engine without the pony truck?

Answer 157.—Raise the engine in front and block between the cross equalizer and the belly of the boiler.

Question 158.—If a cast iron tender or engine truck wheel should break, what would you do?

Answer 158.—Try to block it from turning and skid it to the nearest siding, running very slowly. Then chain up or remove the broken wheel.

Question 159.—Which man is the more economical of oil, steam, coal and time, he who continually carries a boiler too full of water or he who carries several inches less than a full glass?

Answer 159.—Most decidedly the latter. High water men make the poorest records and are the most extravagant, besides frequently breaking cylinder heads, shearing crosshead keys or breaking pins. If you keep close watch of the high water man on the road, you will find that there are many times when his water goes much lower than the other man; for working wet steam first takes too much water from the boiler, then the water supply is increased, steam drops back, the reverse lever is dropped lower to make up for this loss of pressure; this takes still more water and if the run is long and hard it will be difficult to keep the water outside the lower water glass nut.

Question 160.—About what portion of the total power of a locomotive is wasted in friction?

Answer 160.—From 10 to 25 per cent., depending upon the effectiveness of the lubrication and the balancing of the valves.

Question 161.—What part of a locomotive has the greater friction resistance?

Answer 161.—The valve, but this is greatly reduced by well balanced valves.

Question 162.—What does proper lubrication prevent?

Answer 162.—It prevents wear, heat and resistance.

Question 163.—How much oil is useful and necessary for proper lubrication?

Answer 163.—Only the amount that can adhere to the frictional surfaces. Too much oil in cellars and on bearings only runs onto the ground or is thrown all over the engine: too much oil in cylinders only gums up the exhaust passages and nozzles.

Question 164.—What is the purpose of graphite, soap, ammonia, salt, etc., on a hot bearing?

Answer 164.—Chiefly to fill up or glaze over the rough

spots in the bearing surfaces; also these substances will stand a greater heat than oil before running off the bearing.

Question 165.—What is one frequent cause for hot bearings?

Answer 165.—The waste in cellars being too high at the sides, so that threads of it are caught up by the journal and wrapped around it, often catching fire when both journal and box are cold.

Question 166.—What is the best material for packing the cocks in the cab to keep them steam tight and still have them work easily?

Answer 166.—Fill the glands with plumbago or graphite with a ring of asbestos wicking each side, then tighten down solid.

Question 167.—In case of impending collision, what should you do?

Answer 167.—Apply the brakes in emergency, shut off the throttle, whistle for brakes, open wide the sand lever and then protect myself as my best judgment dictates.

Question 168.—Should a man make up his mind beforehand what to do?

Answer 168.—Most assuredly. When in great danger a man has little time for thinking and should act correctly from his premeditated determination. There have been many cases where men acting on the spur of the moment have released their brakes and done other things that tended not in the least to reduce the force of the collision.

Question 169.—With the modern large locomotives is it generally safer to jump off or remain behind the boiler head in case of collision?

Answer 169.—That depends greatly upon the kind of collision. If a rear-end collision, less damage is likely to your locomotive. If a head-on collision with another large locomotive, I should "unload" at once. Going at moderate speed and in a safe place to jump, I would certainly get off. If it were in a cut the cars behind are likely to pile up and render it as dangerous for you as it would be behind the big boiler head.

Question 170.—How is it known that a boiler is carrying the proper steam pressure?

Answer 170.—By the safety valves and steam gauge when the engine pops. No boiler should ever be allowed higher steam pressure than that prescribed by the company.

Question 171.—How should steam gauges and safety valves be tested?

Answer 171.—At least once a month by the use of a test gauge attached to the locomotive.

Question 172.—Why is it not better to remove the gauges and test them?

Answer 172.—Because the temperature of the gauge in the cab has some effect and the more certain way is to have the gauge in its usual position when testing.

Question 173.—How much power have the piston and crosshead on one side to turn the crank pin, when the center wrist pin, the crank pin, and the main driving axle on the same side are in a straight line?

Answer 173.—None whatever.

Question 174.—How then is the engine kept moving?

Answer 174.—The crank pin on the other side is on the quarter, and that being a most powerful position, this causes the wheels to move sufficiently to bring the opposite side off the dead center.

Question 175.—What is meant by "the dead center"?

Answer 175.—When the wrist pin, the main crank pin, and the main driving axle are all in one straight line.

Question 176.—What is the "wrist" pin?

Answer 176.—The pin in the crosshead to which the front end of the main rod is attached.

Question 177.—How should hot bearings be treated?

Answer 177.—They should be cooled down gradually so as to prevent crystallizing and subsequent breakage of the metal. The cause should be ascertained, if possible, whether defective lubrication, foreign substances on the bearing, or defective workmanship, in order to guard against repetition of the same trouble.

Question 178.—What is the objection of filling a tank with water and overflowing it considerably?

Answer 178.—It wastes water, injures the road bed, and in winter the water freezes up the flanges and has to be chopped out.

Question 179.—Should care be taken in opening the blow off cock?

Answer 179.—Yes. Always look first to see no one is near enough to be burned; also do not blow the water and sediment over cars, buildings, or over the engine and tender. It is very injurious to the paint and varnish.

Question 180.—What is meant by the "total wheel-base" of a locomotive?

Answer 180.—The distance from the center of the forward to back wheel of the engine.

Question 181.—What is meant by the "rigid wheel-base"?

Answer 181.—The distance between the centers of the front and the back pairs of driving wheels.

Question 182.—Why are piston rods frequently extended out through the front cylinder head?

Answer 182.—In order to better guide the piston and produce more uniform wear of the cylinders. This is the practice, noticeably, with the large cylinders of compound locomotives.

COMPOUND LOCOMOTIVES.*

Question 1.—Wherein do compound locomotives differ from ordinary or simple engines?

Answer 1.—Compound locomotives differ from the ordinary type in that a simple engine has but one set of cylinders of the same diameter and uses the steam but once, while a compound or double expansion engine has either two or four cylinders of varying diameters, and the steam, after passing through the first cylinder and losing part of its energy, passes into the second cylinder, where a certain amount of its remaining energy is used. The difference between the two types would be plainer if the first builders of compounds had used the phrase "double expansion" instead of "compound."

Question 2.—Why is one cylinder on a compound locomotive called the high-pressure cylinder, and the other one the low-pressure cylinder?

Answer 2.—Because the high-pressure cylinder takes its steam directly from the boiler at nearly initial boiler pressure, while the low-pressure cylinder, under ordinary conditions, receives the steam from the high-pressure cylinder only at greatly reduced pressure.

Question 3.—What are the principal advantages claimed for compound locomotives?

Answer 3.—Economy in the consumption of fuel and water. A compound engine in good order and properly operated does more work with a given volume of steam than a simple engine.

Question 4.—In the Schenectady two-cylinder compound, what is the duty of the oil dash pot?

Answer 4.—The duty of the oil dash pot in the Schenectady compound is to insure a steady movement of the valve without shock.

Question 5.—Is it necessary to know that the dash pot contains sufficient oil, and why?

Answer 5.—The oil dash pot should be kept full of engine oil to prevent the intercepting valve from slamming. Failure or breakage of the intercepting valve can nearly always be traced to lack of oil in the dash pot.

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* The reader is referred to the chapter herein devoted to Compound Locomotives.

Question 6.—Explain how a Schenectady two-cylinder compound may be operated as a simple engine.

Answer 6.—To operate the Schenectady compound (two-cylinder) as a simple engine, the handle of the three-way cock in the cab is moved by the engineer so as to admit either air or steam pressure into the pipe which connects with one end of the separate exhaust valve chamber, forcing the separate exhaust valve (which is otherwise held in its normal position by a spring) from right to left and in the direction of the intercepting valve. Then, as the throttle is opened, steam is admitted directly from the boiler into the passage which communicates with the intercepting valve, forcing the valve from left to right and permitting the steam to pass through it, and leaving it through suitable ports and passages, whence it passes through the reducing valve to the low-pressure steam chest. At the same time steam is admitted directly from the steam pipe to the high-pressure cylinder. Steam is exhausted directly from the high-pressure cylinder to the atmosphere through the receiver and separate exhaust passage, while steam from the low-pressure cylinder is exhausted directly to the atmosphere as usual.

Question 7.—When should a Schenectady compound be operated as a simple engine?

Answer 7.—Only at very slow speeds, when there is danger of stalling, and in starting very heavy trains.

Question 8.—Why not operate as simple when running faster?

Answer 8.—Because it would mean not only a waste of steam and greater consumption of fuel, but also a greater and unnecessary wear and strain to the machinery.

Question 9.—Explain how a two-cylinder compound is changed from simple to compound.

Answer 9.—To change a two-cylinder compound from simple to compound the three-way cock would have to be returned to the normal position, which permits the pressure to be withdrawn from the piston head of the separate exhaust valve. As this pressure is exhausted to the atmosphere, the compressed spring is released and forces the separate exhaust valve to normal position, closing communication. The pressure in the receiver, due to the exhaust from the high-pressure cylinder, will rise and force the intercepting valve to the left, which opens the passage for the exhaust steam from the high-pressure cylinder through the receiver to the low pressure steam chest. The movement of the intercepting valve to the left shuts off the live steam between the boiler and the low-pressure steam chest.

Question 10.—What moves the intercepting valve in a two-cylinder compound?

Answer 10.—The intercepting valve is automatically operated by the steam pressure exerted upon it, due to the difference in the areas of the ends of the valve.

Question 11.—How should a compound engine be lubricated?

Answer 11.—Two-thirds of the allowance for cylinder lubrication should be fed to the high-pressure cylinder while using steam. When drifting for long distances this rule should be reversed, owing to the greater surface exposed in the low-pressure cylinder and the imperfect distribution of oil due to the absence of steam from the cylinders.

Question 12.—Why feed more oil to a high than to a low-pressure cylinder?

Answer 12.—Because part of the oil fed to the high-pressure cylinder is carried along with the steam to the low-pressure cylinder, and the high pressure of steam in the high-pressure cylinder causes more friction than exists in the low-pressure cylinder, and the greater the pressure the greater the friction, and consequently more oil is needed to counteract that friction.

Question 13.—How much water should be carried in a boiler of a compound locomotive?

Answer 13.—Just enough to guarantee absolute safety from overheating the fire-box under all conditions of service.

Question 14.—Why should no more than the amount which you answer for the preceeding question be carried in the boiler of a compound engine?

Answer 14.—In order to assure the delivery of dry steam to the cylinders, as wet steam is particularly injurious to compound locomotives.

Question 15.—How should a compound locomotive be started with a long train?

Answer 15.—Always in simple position.

Question 16.—When drifting what should be the position of the separate exhaust valve, cylinder and port cocks?

Answer 16.—In drifting, the three-way cock in cab should be in the same position as when working the engine simple, which causes the separate exhaust valve to open. The cylinder and port cock should also be open.

Question 17.—What will cause two exhausts of air to blow from the three-way cock when the engine is being changed to compound?

Answer 17.—A weak separate exhaust valve spring or the exhaust valve itself sticking.

Question 18.—What does steam blowing at three-way cock indicate?

Answer 18.—A leaky separate exhaust valve seat and steam passing by the exhaust valve piston packing rings.

Question 19.—What can be done if the engine will not operate as compound, when air pressure on the separate exhaust valve is released by the three-way cock?

Answer 19.—This indicates that the separate exhaust valve is stuck and communication with the separate exhaust valve has not been closed. A small quantity of head-light oil admitted through the oil plug at the three-way cock and forced to the separate exhaust valve, repeating the operation shortly after with cylinder oil, will generally release the valve.

Question 20.—If the engine stands with high-pressure side on dead center and will not move when given steam, where is the trouble and what may be done to start the engine? Why?

Answer 20.—The trouble is due either to a stuck intercepting or reducing valve which prevents direct communication between the boiler and low-pressure cylinder. The position of the intercepting valve stem will indicate which valve is sticking. If the stem extends clear out, it would be the intercepting valve; and, unless some of the parts were broken a light tap on the end of the stem after the throttle is open will send it ahead. If the stem protrudes only a few inches, it will be the reducing valve that is sticking. Usually a few sharp blows on the intercepting valve back head with the throttle open will dislodge it, and direct communication between the boiler and the low-pressure cylinder will be again established. Because the intercepting and reducing valves by their relative positions to the openings in their valve chambers control or prevent the free admission of steam from the boiler to the low-pressure cylinder direct, anything that prevents the free movement of either valve renders both of them inoperative. If the admission of steam into the passage connecting with the intercepting valve cannot move it from its normal position, direct communication between the boiler and low-pressure cylinder cannot be established, and the greatly reduced power conveyed from the high into the low-pressure cylinder is entirely inadequate to move the engine in starting.

Question 21.—In the event of a break-down, how should one disconnect?

Answer 21.—Open the separate exhaust valve as when running simple; then block, cover ports, and disconnect the same as with a simple engine.

Question 22.—What may be done to shut off steam pressure from the steam chest and low-pressure cylinder?

Answer 22.—The separate exhaust valve and intercepting valve should be placed in position to allow the engine to work as a single expansion engine.

Question 23.—Is it important that air be pumped up on a Schenectady two-cylinder compound locomotive before the engine is started? Why?

Answer 23.—Yes, very important, to insure a sufficient amount of air pressure to operate the separate exhaust valve so that the engine can be operated as a single expansion.

Question 24.—How are blows in a compound located?

Answer 24.—That depends entirely on the type. To locate blows or leaks through valves or cylinder packing on two-cylinder compounds, tests are made precisely as with a single expansion engine. The engine should be worked as a simple engine while testing for such blows. To test for blows in the intercepting valve, place the right-hand crank pin on the top quarter and the reverse lever in the center of the quadrant, close intercepting valve and open the separate exhaust valve as when working simple. Steam will pass through the separate exhaust valve and appear at the exhaust nozzle, if the intercepting valve blows.

Question 25.—To what ports are the by-pass valves connected, and why are they used?

Answer 25.—To the steam ports, and they furnish communication between the steam chest and the steam ports in the cylinders. They are used to relieve the cylinders from excessive back pressure when drifting.

Question 26.—Why are the four-cylinder Schenectady compound locomotives in service called tandem?

Answer 26.—Because the high-pressure cylinder is ahead of and connected with the low-pressure cylinder, and both pistons are operated by the same piston rod.

Question 27.—Does the steam in a tandem compound locomotive exhaust from left to right cylinders in a similar manner to the Cross compound?

Answer 27.—No, the steam from the high-pressure passes to the low-pressure on the same side.

Question 28.—Are the valves on a tandem compound designed to give outside or inside admission to steam?

Answer 28.—The valves on a tandem are designed for both inside and outside admission.

Question 29.—What arrangement of steam ports have these engines, so that an outside and inside admission valve may be operated by one valve rod?

Answer 29.—On the high-pressure cylinder the valves are arranged for internal admission, and the steam ports in the high-pressure cylinder are crossed. On the low-pressure, the valves are arranged for external admission and the steam ports are those in use on the ordinary type engine.

Question 30.—Trace the course of the steam from the high-pressure valve to the atmosphere when working compound.

Answer 30.—Since both valves operate on one stem, and as the high-pressure valve is internal and the low-pressure external admission, the ports in the high-pressure cylinder must necessarily be crossed, so that when live steam is admitted to one end of the high-pressure cylinder the exhaust from the opposite end of the high-pressure can pass over into the low-pressure cylinder to exert its energy in the same direction and in unison with the high-pressure. Steam leaving the high-pressure valve and entering the back port in the high-pressure cylinder flows to the forward end of the cylinder, forcing the piston back. After spending its force it is exhausted to the high-pressure steam chest, passing through the center of the hollow high-pressure valve to the outer back edge of the low-pressure valve, enters the back end of the low-pressure cylinder, and after spending its force escapes through the exhaust port of the low-pressure valve directly to the atmosphere.

Question 31.—When and how may a tandem compound be operated as a simple engine?

Answer 31.—Only in starting or when there is a possibility of stalling. It can only be operated as a simple engine when the starting valve is used.

Question 32.—What steam passages have communication with the starting valves?

Answer 32.—The high-pressure steam ports and the passages surrounding the by-pass valve.

Question 33.—How does the manipulation of the starting valves cause the engine to operate as simple?

Answer 33.—The starting valve, which is operated by a lever in the cab, admits live steam directly to the low-pressure cylinder in the following manner: Steam is admitted to the high-pressure steam chest through the short steam pipe connecting the saddle and the chest, passing through suitable ports and around by-pass valves which register with the high-pressure steam ports. The by-pass valves are held against their seats by the pressure from below, which is in direct communication with the chest. The starting valve, having thus established communication with both high-pressure steam ports, steam passes through both hollow piston valves and is admitted to the low-pressure cylinder.

Question 34.—What other valves are in the starting valve casting?

Answer 34.—The by-pass valve.

Question 35.—How many sight feeds to lubricators of a tandem compound, and what do they lubricate?

Answer 35.—There are generally two lubricators each with

a double sight feed and each sight feed lubricating only one of the four valves and pistons.

Question 36.—How should the oil used be distributed?

Answer 36.—When the engine is working, the high-pressure should receive the greater and the low-pressure the lesser quantity, and when drifting these proportions should be reversed.

Question 37.—How should a Schenectady tandem compound be disconnected in case of break-down on the road?

Answer 37.—Just the same as a simple engine with reference to blocking crossheads, covering ports, etc.

Question 38.—Describe in a general way the arrangement of steam pipes, receiver pipes and cylinders in a two-cylinder or Cross compound.

Answer 38.—The steam passes from the dry pipe through a steam pipe to the high-pressure cylinder steam chest, exhausting from that cylinder through a large low-pressure steam pipe which is called the receiver and extends around the inside of the front end to the low-pressure steam chest and cylinder on the other side of the engine, exhausting from there through the exhaust pipe and nozzle.

Question 39.—Give the same information in regard to a Vauclain compound?

Answer 39.—The steam and exhaust pipes are arranged as in a simple engine. The steam from the front side of the high-pressure piston exhausts to the back side of the low-pressure piston (on the same side of the locomotive). There is no receiver except that formed by the hollow piston valve.

Question 40.—What is the difference between a four-cylinder tandem and a Vauclain compound in the arrangement of cylinders?

Answer 40.—The tandem has one cylinder behind the other, the Vauclain Compound has one cylinder above the other.

Question 41.—How many main steam valves has a tandem?

Answer 41.—Four.

Question 42.—How many has a Vauclain?

Answer 42.—Two.

Question 43.—Why are the low-pressure cylinders made larger than the high-pressure cylinders?

Answer 43.—To obtain the necessary area so that the less pressure will be equally as effective as the high-pressure cylinder.

Question 44.—Trace the passage of steam from boiler to atmosphere in a Vauclain compound engine, and state the difference when working simple.

Answer 44.—Dry pipe to steam pipe, to steam chest, past

the ends of the piston valve to the high-pressure cylinders; from there it is exhausted through the hollow piston valves to the low-pressure cylinder, thence it exhausts around the central outside cavity to the exhaust pipe and nozzle. When working simple live steam from the boiler is admitted through a small pipe direct to the low-pressure cylinder and exhausted as usual, the high-pressure piston having equal pressures on both sides and not being of any effect.

Question 45.—In what position should reverse lever and simpling valve be when drifting down grade?

Answer 45.—Lever in full gear, or nearly so, starting valve open for "simple."

Question 46.—With engines which do not have lubricator pipes extending to low-pressure cylinders, what should be done to lubricate low-pressure cylinder when drifting?

Answer 46.—Work a little steam to keep them lubricated.

Question 47.—What device is provided on some engines for this purpose?

Answer 47.—Oil pipes also leading to the low-pressure cylinders.

Question 48.—How would you test for valve blow in a Vauclain compound?

Answer 48.—Place valve in central position covering all ports, open the throttle which admits steam to the ends of the valve. If the two extreme end rings leak, steam will blow steady from the high-pressure cylinder cocks. If the two inside rings leak, there will be a blow from the exhaust nozzle. The packing rings governing the low-pressure cylinder are best tested by placing the lever in the corner, starting valve open and brakes set. Steam would then blow through the exhaust.

Question 49.—How with a tandem?

Answer 49.—Place the engine on the bottom quarter, block wheels, cover ports, remove the indicator plugs on the high-pressure cylinder, give the engine full steam. If tight, it shows that packing rings 2 and 3 are tight. To test the low-pressure valve, open the starting valve, replace the indicator plugs in the high-pressure cylinder and remove those in the low-pressure cylinder; also remove the by-pass valve and screw the cap down. Open the throttle and any blow in rings 5 and 8 will appear at the exhaust.

Question 50.—How would you test for blow in high and low-pressure cylinder packing in each type?

Answer 50.—Both engines alike. In testing for high-pressure cylinder packing, place the reverse lever in the forward motion opening the front port to the high-pressure cylinder. With starting valve closed and indicator plug or safety valve open at the other end of the cylinder. Give the

engine steam and if it blows it will be due to leaky cylinder packing or the No. 7 valve ring blowing. To determine which it is, make a similar test but with the reverse lever in the back motion. If still a blow, it is the high-pressure cylinder packing. If test for low-pressure cylinder packing, put the reverse lever in forward motion, remove only the back indicator plug from the low-pressure cylinder, open the starting valve and see if steam blows out of the plug hole.

Question 51.—How can a blow in sleeve between high and low-pressure cylinder of a tandem be located?

Answer 51.—Shut the starting valve and admit steam to the back end of the high-pressure cylinder. If the steam blows, it will show at the front low-pressure cylinder cock or indicator plug and also blow through the exhaust.

Question 52.—How would you proceed to set a slipped eccentric on a Vauclain compound, or a tandem?

Answer 52.—The same as with a simple engine.

Question 53.—In case it was necessary to disconnect on one side of a Vauclain compound, how would you cover ports and hold valve in position? How in case it was a tandem?

Answer 53.—Place valve in central position in both cases and clamp securely, the same as with a simple engine.

Question 54.—At which end of guides would you block the crosshead, and why?

Answer 54.—Back end, preferably, because if it should get away the knocking out of a front cylinder head is less serious.

Question 55.—How would you disconnect a Vauclain compound for a broken high-pressure piston rod? How for a low-pressure piston rod or piston?

Answer 55.—If too heavy to take down, loosen the cylinder head, remove the indicator plugs and relief valves and run in slowly. Disconnect the valve on that side and clamp it in center.

Question 56.—Explain the working of a Vauclain compound with broken ring in high-pressure valve. Also in low-pressure valve.

Answer 56.—A broken ring in the high-pressure cylinder will increase the pressure in the low-pressure cylinder on that side and consequently cause a heavier exhaust. A leak through the low-pressure packing will cause a blow and besides give a weaker exhaust than should be.

Question 57.—How would these defects be detected?

Answer 57.—See answer to Question 50.

Question 58.—Is there any difference in a broken front or back ring?

Answer 58.—No.

Question 59.—What is the disadvantage of working a com-

pound engine simple for long distances or when unnecessary?

Answer 59.—Loss of fuel, excessive strains and wear, and it would make the engine logy.

Question 60.—Why is it necessary to sand the rail before starting a compound engine?

Answer 60.—Because of greater liability to slip due to the greater power when temporarily working simple in starting.

Question 61.—Is it a disadvantage to work a compound engine at short cut-off, and why?

Answer 61.—Yes, on account of excessive compression and because the work of the two cylinders is best equalized with the lever at about one-half cut-off.

Question 62.—When engine is working under partial load, how should reverse lever and throttle be operated as compared with a simple engine?

Answer 62.—About half stroke and only as light a throttle as required.

Question 63.—Why is it more important to have cylinder cocks open when starting a compound engine than when starting a simple engine?

Answer 63.—The cylinders are larger and there is greater liability of doing damage with water in them.

ELECTRIC HEADLIGHT.*

Question 1.—Are you operating an electric headlight? If so, how long have you had same, and what is the work required each trip to keep it in order?

Answer 1.—The commutator should be cleaned, a new carbon inserted in the lamp, the point of the electrode cleaned, and see that the proper amount of oil is in the bearing each trip.

Question 2.—Describe passage of current through lamp, and tell how arc or light is formed.

Answer 2.—The current flowing from the dynamo is called the positive current and enters the lamp at the binding post and from there passes through a No. 8 insulated copper wire to the bracket, thence through connections to the carbon; then down through the copper electrode and holder to a No. 8 insulated copper wire, through the solenoid, then to the binding post and back to the dynamo. As soon as current passes through the solenoid, it attracts the solenoid armature, which in turn is connected with the levers which clutch the carbon and separates it from the point of the copper elec-

* In this connection the reader is referred to a volume of this series devoted to a description of the appliances of locomotives.

trode. As soon as this separation begins, the current jumps from the carbon to the electrode, and as the distance is increased the current becomes stronger in its effort to jump from one point to the other, and at the same time the current going through the solenoid becomes weakened and releases the solenoid armature until the distance between the carbon and the electrode points is properly adjusted to form the arc. As the carbon gradually burns away and the distance from the carbon and electrode becomes greater, the current becomes weaker going through the solenoid and the carbons are again drawn together by the tension spring until the proper arc is re-established.

Question 3.—If light burns all right while engine is standing, but dies down while running, where would you look for the trouble? How would you remedy it?

Answer 3.—If the light burns all right while the engine is standing but dies down while running, it is an indication that the carbon is jarring through the clutch faster than it is consumed and the clutch spring should be strengthened so as to hold the back edge of the clutch from being jarred upward and thereby releasing carbon. This may also be caused by the tension spring being too tight, thereby forcing the carbons too close together to form the proper arc.

Question 4.—If the light flashes and goes out, and repeats this several times, then goes out entirely, what would be the cause?

Answer 4.—This is probably caused by the carbon being very nearly burned out and the clothes pin holder is fed down so that it just touches the clutch and the jar of the locomotive causes it to flash. This possibly might also be caused by a broken wire under the insulation or both wires being jarred together where there is no insulation—it means a short circuit somewhere.

Question 5.—If the light burns all right when engine is standing, but dies down when running, and the faster you run the more the light runs down, what causes it to die down?

Answer 5.—This condition is caused by the same trouble as in question No. 3 and should be handled the same, for the reason that the faster the locomotive runs, the more jar there is and the more apt the carbon is to jar through the clutch.

Question 6.—If light dies down when you pull out from station, what is the matter?

Answer 6.—This trouble is caused by having too much water in the boiler and working wet steam in the turbine engine.

Question 7.—If your light flashes and goes out for a sec-

ond, then burns brightly for a second, and keeps this up, where would you look for the trouble?

Answer 7.—It is probably caused by a broken wire, a loose wire in the binding post, or insulation worn off both wires allowing them to be jarred together. Examine your lamp thoroughly and see that all screws are tight and isulation good.

Question 8.—If your light burns very dim and engine is working hard, and cab lights are bright, where is your trouble?

Answer 8.—This condition is caused by a short circuit and is probably in your incandescent wiring. The first thing to do is to pull out one of the incandescent wires from the screw, which will determine if the short circuit is in the incandescent wiring. If this does not remedy the trouble, look for a "short" in your lead wires between the dynamo and lamp.

Question 9.—What should you be sure of, when putting in carbons?

Answer 9.—In putting in a carbon you should be sure that the carbon is smooth and straight and will fall through the clutch freely.

Question 10.—If copper electrode burns off during the trip, state probable cause. What effect does it have on the light? Can you prevent it burning more? If so, how?

Answer 10.—The probable cause of electrode burning off during the trip is the speed of dynamo being too high. This is shown by a green light instead of a white light. The burning of the electrode can be stopped at once by throttling the steam which reduces the speed for the time being and then, when you get to the end of your trip, you can report the governor and have the speed re-adjusted.

Question 11.—Why should copper electrode be clean both on point and where it passes through holder?

Answer 11.—The copper electrode should be clean on the point so that the top carbon will touch the copper, for if there is any scale on the end of the copper, it will prevent the carbon from touching the copper and you will therefore not get the proper contact which you must have to get a current. It should also be clean where it passes through holder so that the current will pass from holder to the copper freely, as any foreign substance has a tendency to insulate the copper from the holder.

Question 12.—Give different causes for light burning green. What must be done to stop it burning green?

Answer 12.—The cause for the light burning green is that the copper electrode is burning. This may be caused by the speed of the dynamo being too high, or by the wires from the

dynamo to lamp being connected up wrongly, so that the positive current enters the copper electrode instead of the top carbon. In this case the binding posts should be changed on the dynamo.

Question 13.—If commutator becomes rough and out of round, what should be done with it?

Answer 13.—It should be trued up, which can be done very nicely, if not too badly out of round, by holding a strip of sand paper by the ends on the commutator when it is running. If pretty bad, it should be put in the lathe and trued up, using a very sharp tool for the work, after which the mica strips in the commutator should be filed out a trifle below the surface to be sure that the copper strips do not lag over.

Question 14.—How, and when should commutator be cleaned?

Answer 14.—The commutator should be cleaned at the end of every trip. This should be done with a piece of damp waste endwise on the commutator and then finished with a dry piece of waste. It is not necessary to use sand paper unless the commutator is rough and sparks.

Question 15.—What is the bad effect of holding sand paper except by ends?

Answer 15.—The bad effect of sand paper on the commutator except when held by the ends is to increase the low spots, as the sand paper would then reduce the copper at the low spots as well as the high, where if the sand paper is only held by the ends, it only reduces the high spots on the commutator and therefore trues up the surface.

Question 16.—Why should mica strips in commutator be kept below copper?

Answer 16.—For the reason that the copper, being softer than the mica, wears away more rapidly and therefore the copper becomes a trifle lower than the mica, and the brushes passing over this mica cause the sparking on the copper.

Question 17.—Why should sand paper be used on commutator and not emery cloth?

Answer 17.—Sand paper should be used on commutator, as should there be a piece of sand paper left between the commutator bars where the mica is filed out, the current would not pass through the sand, but the emery being a conductor of current under these circumstances, would cause a short circuit, by allowing the current to pass through the emery.

Question 18.—Do you put any oil in turbine? What kind and how often?

Answer 18.—The turbine engine should be oiled at least once a week to prevent scale on the buckets. Black oil is recommended for this.

Question 19.—How and when do you oil armature bearings?

Answer 19.—The middle bearing should have just oil enough in the cellar to allow the ring in revolving to pass through it and carry the oil up on the shaft. It is very easy to tell when more oil is required by removing the oil cap and noticing whether the ring is carrying the oil. The outside bearing on the cap should be oiled about every trip.

Question 20.—What is the purpose of tension spring No. 93?

Answer 20.—The purpose of tension spring No. 93 is to overcome the pull of the solenoid on the solenoid armature, preventing the same from separating the points of the carbon too far and breaking the arc.

Question 21.—If too tight, does it affect light burning with low steam pressure? If too weak?

Answer 21.—If tension spring No. 93 is adjusted too tight, it will prevent the engine from running with low steam pressure, as, by forcing the carbon points together, the current is not consumed and is therefore backed up into the dynamo which creates a heavy current. If adjusted too weak, it will allow the solenoid to separate the carbon points too far, thereby breaking the arc.

Question 22.—If commutator sparks badly, what would you do?

Answer 22.—If the commutator sparks badly and the sparking cannot be stopped by the adjustment of springs on the brushes, it should be trued up with sand paper as stated above, and then if the sparking does not cease, the face of the brush should be refitted to the commutator.

Question 23.—Why should commutator be cleaned endwise and not round?

Answer 23.—If the commutator is cleaned "round," there is a tendency for dirt to lodge in the creases between the copper strips, which allows the current to pass through the dirt; the commutator should therefore be cleaned lengthwise, so that these creases will be kept clean.

Question 24.—If light does not start when turning on steam, what would you do?

Answer 24.—The point of copper should be examined to see that there is no foreign substance to prevent the carbon touching it, that the proper tension is on the brushes and that the commutator is clean, and then if the light does not start, a carbon or piece of wire or something which will carry current, should be placed across the binding posts and then removed suddenly. If there is a flash upon removing same, the dynamo is all right and then if the light does not start, the trouble is in the lamp.

AIR BRAKE QUESTIONS AND ANSWERS—THIRD SERIES

AIR PUMP.

Question 1.—Explain how an air pump should be started and run on the road.

Answer 1.—It should be started slowly to permit the condensation to be drained off. The lubricator should be started carefully and the pump worked slowly until about forty pounds has been accumulated in the main reservoir to cushion the steam and air piston of the pump. Then the throttle should be opened wider, giving a speed of about one hundred and thirty or one hundred and forty single strokes per minute. The amount of work being done really governs the speed of the pump.

Question 2.—How should the steam end be oiled?

Answer 2.—By the sight-feed lubricator, with a good quality of valve oil, and at the rate of about one drop per minute. This amount will vary with the condition of pump and the work being done.

Question 3.—How should the air end of the pump be oiled, and what kind of oil used?

Answer 3.—High-grade valve oil, containing good lubricating qualities and no sediment, should be used. A good swab on the piston rod will help out a great deal. Oil should be used in the air cylinder of the pump sparingly but continuously, and it should be introduced on the down stroke, when the pump is running slowly, through the little cup provided for that purpose, and not through the air suction valves. An automatic oil cup, such as has recently come into practice, is preferable to hand oiling.

Question 4.—Explain the operation of the steam end of the pump—on an up-stroke; on a down-stroke.

Answer 4.—When first admitting steam to the 9½-inch pump, if the main piston is at the bottom of the cylinder (as it usually is, due to gravity), the main valve moves to the right hand position pulling with it the side valve and thus admitting steam to bottom of the cylinder under the piston, forcing it up; when the main piston is nearly at the top of its stroke, the reversing plate catches the shoulder on the reversing-valve rod, moving the reversing rod and valve to their upper positions, where it admits behind the large head of the main valve, forcing this main valve over to the left, carrying with it the slide valve which admits steam to the top end of the cylinder and at the same time exhausts it from the bottom end, thereby reversing the stroke of the pump.

Question 5.—Explain the operation of the air end of the pump on an up-stroke; on a down-stroke.

Answer 5.—The air piston is directly connected with the steam piston, and any movement of the steam piston will consequently be transmitted to the air piston. When the steam piston moves up the air piston will, of course, go with it, thus leaving an empty space or a vacuum in the lower end of the air cylinder, underneath the air piston. Atmospheric air rushes through the air inlet, raising the lower receiving valve, and filling the bottom end of the cylinder with atmospheric pressure. At the same time the air above the air piston will be compressed. The pressure thus formed holds the upper receiving valve to its seat and when a little greater than the air in the main reservoir, the upper discharge valve will lift and allow the compressed air to flow into the main reservoir. When the piston reaches the top of the stroke its motion is reversed, and on the down stroke the vacuum in the upper end of the air cylinder is supplied by atmospheric pressure passing through the upper receiving valve. The main reservoir pressure is held by the upper discharge valve, and the air being compressed in the bottom of the cylinder holds the bottom receiving valve to its seat, and when compressed sufficiently, forces the lower discharge valve open and passes to the main reservoir.

Question 6.—Give some of the causes of a pump running hot.

Answer 6.—First, air cylinder packing rings leaking. Second, discharge valves stuck closed or the discharge passages so obstructed that the pump will be pumping against high pressure continually. Third, poor lubrication. Fourth, high speed. Fifth, discharge or receiving air valves leaking. Sixth, air piston rod packing leaking.

Question 7.—If a pump runs very hot on the road, how will you proceed to cool it?

Answer 7.—First, reduce the speed of the pump, and look for leaks in the train line. Second, make sure that the packing around the piston rod is not too tight and in bad condition. Third, see that the main reservoir is properly drained. If the pump still runs hot it should be reported at the end of the trip.

Question 8.—If the pump stops, how can you tell whether the trouble is in the pump or in the governor?

Answer 8.—It may be tested by opening the drain cock in the steam passage at the pump, and noting whether there is a free flow of steam; if so there is a free passage through the governor and the trouble is not there.

Question 9.—State the common causes for the pump stopping.

Answer 9.—There are several reasons. First, it may be stopped by the governor being out of order. Second, the valves may be dry and need lubrication. Third, nuts may be loose or broken on the piston rod or one of the pistons pulled off. Fourth, the reversing valve rod may be broken, or bent, or the reversing plate may be loose, or the shoulder on the reversing valve rod or on the reversing plate may be so badly worn as not to catch and perform their proper functions. Fifth, nuts holding the main valve piston may be loose or broken off. Sixth, excessive blow past the packing rings of the main valve.

Question 10.—Under what circumstances will a pump compress air in but one direction?

Answer 10.—With either discharge valve broken and held off its seat.

Question 11.—How will defective air valves affect the operation of the pump?

Answer 11.—Leaky air valves, like leaky air cylinder packing, cause a pump to heat badly and lose greatly in the amount of air compressed. A broken air valve causes the loss of all service of compression at that end of the pump, that is, makes it single instead of double acting. See also Answer 6.

Question 12.—How do you locate these defects?

Answer 12.—By the way the pump acts. The main piston moves quickly toward a broken receiving valve and away from a broken discharge valve. The various defects all have their symptoms, which are noticed if the principle of the pump and its details are clearly understood.

Question 13.—Should an engineman observe the working of a pump on the road so as to properly report defects or repairs needed, and do you consider yourself competent to locate defects?

Answer 13.—Yes.

Question 14.—If the pump stops on the road, what will you do to start it?

Answer 14.—I would close the steam valve a moment and then open it quickly. If it then failed to start, it would indicate that the main valve was broken. I would also examine it in both air and steam end for defects. Be sure, first, that the governor is not defective or has not shut off the supply of steam to the pump.

NEW YORK AIR BRAKE. THE DUPLEX AIR PUMP.

Question 1.—Describe the New York Duplex Air Pump and its operation in the steam end.

Answer 1.—It has four cylinders—two steam and two air; one air cylinder is double the area of any one of the other

three, which are all the same size. The steam end is duplex, and the piston in each steam cylinder operates the slide valve which controls the flow of steam from the boiler into the opposite steam cylinder and out to the atmosphere. This is done by locating the slide valve for the right cylinder under the left cylinder, and for the left cylinder under the right one, and cross the steam ports from the left valve to the right cylinder and from the right valve to the left cylinder. The valves are D slide valves which admit steam to the cylinder by the outside edge of the valve and exhaust through a cavity in the center. The seat has three ports, two steam with the exhaust port between them. A reversing valve rod is attached to the steam valve and extends into the steam cylinder; the main piston rod is drilled to clear this valve rod within it and a plate is bolted on to the steam piston in such a manner as to strike a shoulder on the valve rod just before the stroke of the piston in either direction is completed, changing the steam valve to its opposite position in the steam chest. Both steam valves being down, when steam is turned on the right piston makes a stroke up and at the completion of the stroke changes its steam valve, causing the left piston to make a stroke up, changing its steam valve at the completion of the stroke, and causing the right piston to move down, etc. The steam cylinders are the two bottom cylinders.

Question 2.—Describe the operation of the air end.

Answer 2.—The large piston compresses air into the smaller cylinder and then the latter compresses it into the main reservoir.

Question 3.—Is this a compound pump in both steam and air ends, or in the air end only?

Answer 3.—Only in the air end.

Question 4.—What defects in the steam end will stop the pump? How do you locate them?

Answer 4.—Chiefly the reversing apparatus—the reversing plates and rods. Would investigate until the trouble was found, bearing in mind the main valve for one cylinder regulates the steam in the other.

Question 5.—What defects in the air end will stop the pump? How do you locate them?

Answer 5.—Generally broken piston rods or loose nuts. Broken or defective valves cause the pump to go "lame" but seldom stop the pump unless broken parts get into the cylinder. Remove the top heads to get at the air cylinders and examine the valves through their caps.

Question 6.—Explain how you will locate a blow of steam by the piston or main steam valves.

Answer 6.—It is difficult to distinguish between leaky

packing rings, leaky slide valves and worn cylinder. These parts should be removed and examined carefully when there is a bad blow.

Question 7.—What is the cause of the pump not exhausting square or working lame?

Answer 7.—Any one or more of the air valves stuck or broken or if they have much different "lift."

Question 8.—What is the effect of leaky piston rod packing in the high pressure air cylinder?

Answer 8.—Any defective or leakage in the smaller or high-pressure cylinder is more serious than in the low-pressure cylinder because the pressure in the former is so much higher that the consequent loss is greater. This loss of compressed air to the atmosphere will cause the pump to run faster in order to maintain the same pressure.

Question 9.—What is the effect of leaky piston rod packing in the steam cylinders?

Answer 9.—A waste of steam, obstructing the vision in the winter and causes the piston rods to cut and groove.

Question 10.—Explain how you would locate a defective air valve.

Answer 10.—The general rule is this: the piston jumps toward a leaky or broken receiving valve and away from a broken or leaky discharge valve; also in the latter case the pump heats up more, as the compressed air is "churned," that is, pumped over and over again. Air blowing out of the low-pressure receiving valves is readily detected.

Question 11.—How should the air cylinders be oiled? The steam cylinders?

Answer 11.—In the air cylinders use good valve oil very sparingly. Always keep good, well oiled swabs on the piston rods, as it has been proven by many careful engineers that with these practically no oil need be put into the air cylinders. Valve oil in the steam cylinders and lubrication started directly after the pump has started. Remember the first steam admitted to a cold pump condenses and washes the surfaces clean of oil; hence oil should be supplied immediately thereafter.

Question 12.—Which air cylinder requires the most oil?

Answer 12.—The smaller or high-pressure cylinder, on account of the higher temperature.

Question 13.—Explain the operation of the automatic oil cup used on the air cylinders.

Answer 13.—With the oil cup filled, the pump working and the stroke of the piston upward, air is forced up through a small passage in the center of the oil cup body and cap, down inside the extended cap nut sleeve, through the oil and forms a pressure thereon. When the piston is on its

downward stroke, and there is a partial vacuum in the air cylinder, the air pressure formed on top of the oil in this cup forces the oil up inside the sleeve of the cap nut to the feed port and a small quantity of oil is then taken down through this port and sprayed into the air cylinders on each down stroke.

NEW YORK ENGINEERS' BRAKE VALVE.

Question 1.—Name the positions of the handle of this valve.

Answer 1.—Release, running, positive lap, service graduating (divided into five notches) and emergency.

Question 2.—Describe the flow of air through the valve in each of these positions.

Answer 2.—Release, from the main reservoir to the train pipe through large opening. Running position, from the main reservoir past the excess pressure valve (when open) to the train pipe. Positive lap, all ports closed except port "O" to chamber "D." Service graduating, small opening from the train line through the main slide valve to the atmosphere, which opening is finally closed by the graduating slide valve when the certain reduction has been made. Emergency position, a large direct opening between the train line and the atmosphere.

Question 3.—What is the duty of the supplementary reservoir? In case the connections to this reservoir are broken or leaking badly, what will you do, and how will you make a service reduction in the train pipe?

Answer 3.—To enlarge chamber "D" plug it up and make service reductions in the first or second graduating notch, bringing the handle back to positive lap when by the gauge you found a sufficient reduction has been made.

Question 4.—By what pressure is this reservoir charged?

Answer 4.—Train pipe pressure.

Question 5.—Explain the difference in the manner of charging this reservoir in the style "A" pattern of brake valve and in the style "B," the later pattern of valve.

Answer 5.—With the style "A" valve the handle must be left a moment or moved slowly over running or positive lap positions in order to fill this supplementary reservoir and thus be ready for service graduations. With the style "B" valve the equalizing piston returns to its normal position no matter in what position the brakes have previously been released.

Question 6.—What is the duty of the equalizing piston? Explain its operation in a service reduction.

Answer 6.—To stop the discharge of air from the train pipe without causing the release of any of the head brakes on the train. When the train pipe pressure in chamber "A" becomes enough less than that in chamber "D," the piston is gradually moved and closes the graduating slide valve.

Question 7.—How will you distinguish the new pattern of brake valve from the older one?

Answer 7.—The cap to chamber "D" has a larger projection due to the provision made for the vent valve with style "B."

Question 8.—Explain the operation of the style A valve in a service application. In an emergency. In a release of brakes and re-charging the supplementary reservoir.

Answer 8.—With the style "A" valve, if the previous release had been made in running position instead of full release, the equalizing piston would not return to its normal position because no air had been exhausted from chamber "D", hence no response would be had to the next service application until the handle had been moved to the next graduating notch beyond one used in previous application. Also, as explained in Answer No. 5, care had to be taken to fill chamber "D" and the equalizing reservoir between two applications. Both types of valves work alike in emergency application.

Question 9.—Explain the operation of the style "B" valve in an application. In a release of brakes.

Answer 9.—The style "B" valve works practically the same in an application of the brakes only that in case of a second application after release there is no trouble in keeping the equalizing reservoir properly charged and the graduating feature is reliable in all its notches for repeated applications.

Question 10.—Why is it not necessary to move the handle of the valve to lap position between reductions in a service application?

Answer 10.—Because the graduating slide valve laps the ports by its automatic movement received by the graduating piston after the reduction corresponding to the service notch has been made.

Question 11.—What are the plugs for that are in the cap of the brake valve?

Answer 11.—So that the main slide valve can be oiled without taking the brake valve apart.

Question 12.—How will you test for leaks in either pattern of brake valve?

Answer 12.—With valve "A," to test for leaky main slide valve place the handle in the last service notch, close the stopcock under the brake valve and watch for any rising of the black hand in the gauge. With the style "B" valve, place in

emergency position then to positive lap, close the stop-cock and notice if the black hand rises. To test the small cut-off or graduating valve after ascertaining that the main slide-valve is tight, make a reduction in the second service notch, then close the stop-cock. If a blow is heard at the exhaust port and the black hand falls slowly, the cut-off valve is leaking.

GOVERNOR.

Question 1.—What is the duty of the pump governor?

Answer 1.—To properly regulate the air pressure in the main reservoir.

Question 2.—Explain how the governor operates.

Answer 2.—The governor is an automatic arrangement for admitting and closing off steam to the air pump, and is actuated by air pressure. The steam valve, which shuts off and opens up the steam passage way to the pump, is controlled by an air piston and spring. When air pressure is admitted above the piston, it forces the piston down, closing off the steam to the pump. When the air pressure is exhausted from above the piston, the spring forces the piston up and allows steam pressure to pass to the pump. The admission and exhaust of the air to this piston is controlled by a diaphragm and spring. The air from the main reservoir enters the body of the governor underneath the diaphragm, which is held by a spring of given tension, depending on the pressure desired in the main reservoir. While the main reservoir pressure is less than the pressure the governor is set for, this diaphragm is held down by the spring, and the air can pass no further than a small pin valve attached to it, but when the main reservoir pressure overcomes the tension of the spring, it raises the diaphragm, unseats the pin valve and allows the air to flow to the top of the air piston, shutting off the pump. During the time the air is acting on this piston some of it escapes through a leakage port or vent hole, which is always open. When the main reservoir pressure drops below that to which the spring is adjusted, the spring forces the diaphragm down, seating the pin valve and allowing the air on top of the piston to escape to the atmosphere, through the small vent port.

Question 3.—By what air pressure is the governor operated when using the D-8 brake valve? When using the G-6 valve? When using the New York brake valve?

Answer 3.—With the D-8 valve, by train line pressure. With the F-6 or G-6 valve, by the main reservoir pressure. New York, by the train line.

Question 4.—By what pressure is the duplex governor

operated in high speed service? By what pressure in ordinary service?

Answer 4.—The governor tops are adjusted for 90 and 110 pounds and the two feed valves are set for 70 and 90 pounds. To operate the low or ordinary pressure feature, the handle of the reversing cock is turned to the left, this cuts out the 110 pound governor and 90 pound feed valve and renders operative the 90 pound governor and 70 pound feed valve. By reversing the position of the reversing cock handle the low pressure parts are cut out and the high-pressure parts cut in; but the small stop cock in the governor pipe must also be closed.

Question 5.—What is the object of the relief port in the governor? Why should it be kept open?

Answer 5.—If this port is not kept open, the air pressure which holds the piston down cannot escape when the diaphragm valve closes and consequently the governor will not operate the pump properly.

Question 6.—If the pin valve leaks, what effect will it have on the pump?

Answer 6.—It will allow a certain amount of air pressure to flow in on top of the air piston. If the leak is greater than the escape from the little leakage port, the under pressure will accumulate, and cause the governor to slow down or completely stop the pump.

Question 7.—How can you detect leaks in the governor?

Answer 7.—By disconnecting the upper from the lower section of the governor, then attaching the air pressure connection, turn the air pressure under the diaphragm. If it raises with the proper pressure and opens the port the escape of air will be readily noticed. Should it not be raised or the port be closed by dirt, it would be in that section, this will also show if the diaphragm leaks. I would then inspect the lower section.

Question 8.—Where would you look for the cause if the governor allowed the pump to raise the pressure too high?

Answer 8.—The main reservoir pressure may not reach the governor, due to the stoppage in the pipe, or in the union at the governor. This may also be due to the space on top of the diaphragm being filled with dirt. If the air is getting to the diaphragm valve, and is so indicated by the blow at the leakage port, the trouble must then be due to the drip pipe being stopped up or frozen, thereby preventing the air and steam, which leak in under the air piston, from escaping.

Question 9.—Where, if the pump stopped when the pressure was too low?

Answer 9.—If the pump was not getting steam it would probably be due to the pin valve gummed up or dirt under it;

the detector hole or leakage port in the side of the governor would then blow. Once in a great while the piston and steam valve have been known to stick closed but very rarely.

Question 10.—What effect does it have on the pump if the drip pipe is stopped or frozen up?

Answer 10.—The governor cannot then act to shut off the pump and too high a pressure will be pumped into the main drum.

MAIN RESERVOIR.

Question 1.—What is the main reservoir used for?

Answer 1.—The main reservoir is for the purpose of storing a supply of air in advance of its use for all purposes.

Question 2.—Why does water accumulate in the main reservoir, and how often should it be drained?

Answer 2.—The atmosphere contains moisture which is precipitated by compression and settles in the main drum which should be drained daily and at a time when the reservoir is warm enough to be certain no ice could remain therein.

Question 3.—What is excess pressure, and what is it for?

Answer 3.—Excess pressure means simply "additional" pressure or more pressure in the main reservoir than in the train line. For example, if the train line has 70 pounds and the main reservoir 95 pounds, there would be 25 pounds of excess pressure. Again, if the train line had 90 pounds and the main reservoir 115 pounds there would still be 25 pounds of excess.

ENGINEER'S BRAKE AND EQUALIZING DISCHARGE VALVE.

Question 1.—Name the different positions of the brake valve and trace the flow of air through it in each position.

Answer 1.—Full release, running position, lap, service application and emergency application. In full release there is a large direct communication between the main reservoir and the train pipe. In running position the air passes from the main reservoir indirectly to the train pipe, that is through the ports and passages of the excess-pressure valve or through the feed-valve, as the case may be. In lap position all ports are closed. In service application first the air from the equalizing discharge reservoir and cavity "D" escapes to the atmosphere, then, when the equalizing discharge piston raises, the air from the train pipe escapes to the atmosphere through the train line exhaust elbow. In emergency position a large direct opening is made between the train pipe and the atmosphere.

Question 2.—Where does the main reservoir pressure begin and end? Where does the train pipe pressure begin and end?

Answer 2.—The main reservoir pressure begins at the pump discharge pipe and ends at the connection to the brake valve. The train pipe pressure begins at the brake valve and extends to the rear cock on the train, with branches to the triple valve under each car, the tender, and the engine.

Question 3.—Explain the effect of a cut rotary valve or seat.

Answer 3.—A leaky rotary valve or seat usually causes a loss of excess pressure in running position and releases the brakes in lap position.

Question 4.—How do you regulate the excess pressure with each form of brake valve? How do you clean the valves?

Answer 4.—With the 1889 (D-8) brake valve, by the excess pressure spring; with the later forms of brake valves, by the spring in the feed-valve attachment. Clean the valves and their seats by waste or friction from a soft piece of wood—never oil them when replacing.

Question 5.—How do you apply and release the automatic brake?

Answer 5.—The automatic brake is applied by reducing the train pipe pressure below that in the auxiliary, it is released by increasing the train pipe pressure above that in the auxiliary. The brake valve is the valve to properly perform these functions, when everything is in working order.

Question 6.—What can be learned by noticing the discharge of air from the train pipe exhaust?

Answer 6.—The length of the train line, that is, approximately the number of cars of air. By watching this exhaust it can also be determined if, in testing brakes, one defective triple sets quick action; third, in releasing brakes it can be told if you only have the lone engine.

Question 7.—What is the duty of the small reservoir connected to the brake valve? If the pipe leading to this reservoir is leaking badly or broken off, what will you do?

Answer 7.—It is for the purpose of enlarging chamber "*D*" without making a great bulky brake valve in the cab. Plug up this pipe or put in a blind gasket, also plug the train line exhaust nipple and use emergency position carefully, as with the old three-way cock.

Question 8.—Where is the first air taken from in making a service stop? Where does it blow out? Where next?

Answer 8.—From chamber "*D*" and the equalizing reservoir. It blows out of the preliminary exhaust. Next, the train pipe pressure escapes from the train line exhaust nipple.

Question 9.—Does air ever blow out of the train pipe exhaust when releasing the brake? Why?

Answer 9.—Yes, with a lone engine or very short train, in which case the train line charges more rapidly than chamber "*D*" and the equalizing reservoir, thus causing piston 17 to raise.

Question 10.—What pressures do the red hand and black hand of the gauge indicate?

Answer 10.—Red hand—main reservoir; black hand—chamber "*D*" pressure.

Question 11.—Does the black hand of the gauge also show the train pipe pressure at all times?

Answer 11.—No, only when chamber "*D*" and the train line are connected, as in full release and running position. On lap or in service positions at the instant the train line exhaust starts or stops, they are also practically equal.

Question 12.—What will be the result of leaving the handle of the brake valve in full release position too long and then moving to running position?

Answer 12.—Brakes are likely to drag due to temporarily shutting off all supply of air to overcome the leaks.

Question 13.—How is the train pipe pressure regulated with each type of brake valve?

Answer 13.—By the governor with the 1889 (D-8) brake valve; by the feed-valve attachment with all later types of brake valves.

Question 14.—In making a service application what should the first reduction be?

Answer 14.—From 5 to 8 pounds, depending upon the length of the train.

Question 15.—What reduction from seventy pounds train pipe pressure will fully apply the brake? Why?

Answer 15.—About 20 pounds; because that amount from the auxiliary reservoirs will equalize with the pressure in the brake cylinders at about 50 pounds.

Question 16.—How do you handle the brake valve to apply the brake in the emergency?

Answer 16.—It should be thrown to full emergency position and left there.

Question 17.—How do you handle the brake valve in the case of a bursted hose?

Answer 17.—Place the handle on lap. If the trainmen could not find the burst hose, I would frequently throw a wave of air into the train pipe (in running position or partial release) so as to aid them.

Question 18.—In case the train breaks in two?

Answer 18.—Place the brake valve on lap until the rear cock of the first section is closed; then release and as soon as

these brakes are off, place the handle again on lap to get pressure to release the rear portion of train when coupled up. Do not recharge to full pressure until the whole train is coupled up.

Question 19.—When the train is backing up and a tail hose is used on rear end to apply brakes?

Answer 19.—Always carry the valve in running position when the tail hose is being used. Never throw it to full release unless the train stops and some brakes fail to release.

Question 20.—Do leaks in the brake valve affect the operation of the brakes?

Answer 20.—Yes. If air leaks to the atmosphere it will effect the reduction desired. If it leaks from the main reservoir to other ports it may release the brakes or make the service application position of no effect.

Question 21.—Name the defects in the brake valve and explain how you would locate them.

Answer 21.—Leaky rotary valve (or body gasket) place the valve in service position, bleed the engine and tender auxiliaries and place the rear tank hose in a bucket of water. Air bubbles in the water will indicate this leak. If the rotary and body gasket are tight, loss of excess means dirty or cut feed-valve or broken feed-valve gasket. Leaky packing ring in piston 17 (the equalizing discharge piston) makes the gauge reduce slower and the black hand recoil after a considerable reduction. A leak in chamber "*D*" or its connections (the gauge and the equalizing reservoir) causes the train line exhaust to blow and the brakes to set on lap position. These are the main defects and "symptoms."

Question 22.—In what manner can you remedy these defects?

Answer 22.—Carefully tighten the bolts or unions where gaskets are leaking and clean any dirty valves without scratching them; after that is done it is better to handle the valve carefully until the terminal is reached and report the repairs needed in detail.

STRAIGHT AIR BRAKE.

Question 1.—What additional parts are needed on an engine and tender to have the straight air brake in connection with the automatic brake?

Answer 1.—The straight air brake is designed to operate on the engine and tender alone, and not on the cars of the train. To operate the combined automatic and straight air brake, extra parts as follows should be supplied: Reducing valve for the straight air system, set at 45 pounds; an engi-

neer's straight air brake valve; a double seated check valve for the driver brake cylinder; a double seated check valve for the tender brake cylinder; a safety valve, set at 53 pounds, one for the driver brake cyclinders and one for the tender brake cyclinder; and a straight air brake hose connection between the engine and tender.

Question 2.—What is the duty of the double check valve, and how does it operate?

Answer 2.—To prevent air escaping from the brake cylinder through the triple exhaust port while the straight air is applied, also to prevent the air escaping from the brake cylinder through the straight air brake valve exhaust port while the automatic brake is applied. It consists of a double piston with a leather face on each. When the automatic brake is applied the piston is forced to such a position as closes the straight air side and at the same time opens a set of ports that admits the air to the brake cylinder. When the straight air is applied just the reverse occurs and air from the main reservoir, through the straight air brake valve, is admitted to the brake cylinders.

Question 3.—What pressure should the reducing or feed valve used with this brake be set at? The safety valve?

Answer 3.—Reducing valve set at 45 pounds. Safety valve set at 53 pounds.

Question 4.—How do you operate the straight air brake?

Answer 4.—By placing the handle of the brake valve forward in application position, the application valve is opened admitting air from the main reservoir to the brake cylinders; by placing the handle of the valve back in release position, the release valve is opened allowing the air in the brake cylinders to flow to the atmosphere. Lap position is intermediate and in this position both valves are closed.

Question 5.—In what position should the automatic brake valve be when releasing the straight air brake?

Answer 5.—The automatic valve should be carried in running position with excess when using the straight air brake.

THE TRIPLE VALVE.

Question 1.—What is the duty of the triple valve?

Answer 1.—The duty of the triple valve is, first, to charge the auxiliary reservoir, second, to set the brakes by allowing auxiliary pressure to flow to the brake cylinder, and third, to release the brakes by allowing the pressure in the cylinder to escape to the atmosphere.

Question 2.—Why is the word triple used to designate this valve?

Answer 2.—Because it performs the three functions mentioned.

Question 2*a*.—By what is it connected to the brake valve?

Answer 2*a*.—By the branch pipe and the train line with hose.

Question 3.—Explain the duty of the triple piston, the slide valve and the graduating valve.

Answer 3.—The duty of the triple valve piston, is, by variation of pressures on its two sides, to move the slide valve on its seat to the application, graduating, and release position, and to open and close the feed groove in the piston bushing. The function of the slide valve is, by its movement due to the triple valve piston, to make connection between the auxiliary reservoir and brake cylinder, applying the brake, and to make connections between the brake cylinder and the atmosphere, releasing the brake. The function of the graduating valve is, from its movement given by the triple piston, to admit pressure gradually from the auxiliary reservoir to the brake cylinder in response to reductions made in the train pipe pressure.

Question 4.—How many kinds of triple valves are in use on this road?

Answer 4.—Two, the plain type and the quick action type, or according to the fact.

Question 5.—Describe how each kind operates.

Answer 5.—With the quick action type, a sudden reduction of pressure in the train pipe will cause the triple piston and its parts to be moved to quick action application position, which first throws into operation the emergency feature of the triple, admitting train line pressure to the brake cylinder, after which auxiliary reservoir pressure is permitted to pass to the brake cylinder, and consequently a higher pressure is obtained than in a full service application of the brake. With the plain type any sudden reduction merely moves the parts to their extreme position but allows no other than auxiliary reservoir pressure to flow to the brake cylinder.

Question 6.—Explain where the air comes from that enters the brake cylinder in a service application. In an emergency application. With each kind of triple valve.

Answer 6.—In service application with either type of triple valve the air that enters the brake cylinder comes from the auxiliary reservoir; with the quick action triple only does part of the train pipe air first enter the brake cylinder quickly, later followed by the auxiliary pressure.

Question 7.—How do you cut out a triple valve so its brake will not operate?

Answer 7.—The old style plain triple, by turning the handle down obliquely to about 45°. With the later style and all quick action triples, by closing the stop cock in the branch pipe. You should then bleed the auxiliary reservoir.

Question 8.—If a triple valve does not apply the brake at the proper time, where will you look for the trouble?

Answer 8.—If the auxiliary is charged, the triple valve is probably frozen or stuck or the packing ring worn badly, or the brake cylinder itself leaking badly. If the auxiliary has not charged the feed groove may be closed or the reservoir itself be leaking badly.

Question 9.—If the brake will not release, where will you look for the trouble?

Answer 9.—Retainer turned up or its pipe stopped up; triple piston packing ring worn; triple strainer stopped up or triple frozen.

Question 10.—Name the common defects of the triple valve and explain how you locate them.

Answer 10.—Triple valve frozen or stuck, packing ring leaking, etc., located as above. Emergency gasket leaking—cut the car out underneath and the brake will set quick action. Slide valve dirty or leaking—blows through the exhaust or retainer but will not cause emergency as last stated. Brake fails to release on long train, usually the piston packing ring or cylinder bushing worn badly.

HIGH SPEED BRAKE.

Question 1.—Name the complete parts that are added to the ordinary brake to make the latter a high speed brake.

Answer 1.—Two feed-valve attachments with reversing cock, a Siamese fitting with two pump governor tops, and one high speed automatic reducing valve connected by piping to each brake cylinder on the engine and cars.

Question 2.—How much pressure is carried in train pipe and auxiliaries with high speed brake?

Answer 2.—110 pounds.

Question 3.—How would you change from low to high, or from high to low pressure?

Answer 3.—Turn the reversing cock so the 70 pound feed-valve would regulate the train pipe pressure and cut in the cock to the low-pressure governor top; change both these cocks and you are ready for the high speed brake.

Question 4.—How many pounds train pipe reduction in a service application will give a fully applied brake?

Answer 4.—About 20 pounds.

Question 5.—At what pressure will the auxiliary reservoirs and brake cylinders equalize with an emergency application using the high speed brake?

Answer 5.—At about 85 pounds with a 7-inch piston travel.

Question 6.—Explain in a general way the operation of the reducing valve in service and in emergency.

Answer 6.—The valve consists of a piston and stem whose downward movement is regulated by the adjusting spring. A small slide valve with a triangular escape port is attached to the upper side of the piston. If the adjusting spring is set at 60 pounds, and an emergency application of the brake be made, the piston will descend when 60 pounds has been accumulated in the brake cylinder, and the apex or smallest part of the triangular port will permit brake cylinder pressure to pass through it and escape to the atmosphere; as the brake cylinder pressure reduces, the piston will gradually move up a larger part of the triangular port, thus increasing the opening for the escape of brake cylinder pressure to the atmosphere. When the brake cylinder pressure has blown down to 60 pounds, the port will be closed, shutting off further escape of brake cylinder pressure to the atmosphere. In service application, the larger portion of the triangular port will permit brake cylinder pressure to escape to the atmosphere when 60 pounds has been accumulated in the brake cylinder, thus blowing down the pressure quickly and preventing more than 60 pounds being accumulated in the brake cylinder in service application.

Question 7.—If a train with high speed brakes should pick up a car not equipped with same, what should enginemen do?

Answer 7.—Unless a safety valve is at hand to screw into the cylinder oil hole on the car, the only perfectly safe way against wheel sliding in case of emergency would be for the engineer to discontinue the use of the high speed brake on the whole train.

Question 8.—When a car that is equipped with an ordinary brake is coupled to a train using the high speed brake, what must be done with this car to run it with the high pressure?

Answer 8.—Screw a safety valve into the cylinder of this car.

Question 9.—How many full service applications can be made without recharging, and have left as much pressure as is used with the ordinary quick action brake?

Answer 9.—Two. The first one from 110 to 90; the second, 90 to 70.

Question 10.—Should the emergency be used with the high speed brake at a speed of less than forty miles per hour? Give reason.

Answer 10.—It should not, as the wheels will more than likely be slid for the automatic reducing valves do not have time to release the extra pressure before the speed is so slow that the wheels will slide.

THE WATER BRAKE.

Question 1.—Explain the principle upon which the water brake works.

Answer 1.—When a locomotive is reversed the cylinders form powerful compressors, tending to retard the engine greatly but at the same time it is liable to cut the cylinders besides forcing air, gases, and smoke through them into the boiler. Hence a small jet of hot water is piped from a globe valve in the cab (which valve is on a level with the crown sheet) to the two exhaust passages in the cylinder saddles.

Question 2.—Where is it intended the water brake should be used, and what is the object of using it instead of the air driving wheel brakes?

Answer 2.—In mountain service only, its object being to hold the train while recharging the auxiliaries with air; it also allows the driver brakes to be released before the tires get so hot as to become loose.

Question 3.—What must be done with air driver brakes before water brake is put into action?

Answer 3.—They should either be cut out or the bleeder left open.

Question 4.—In what position should reverse lever be placed before putting water brake into action?

Answer 4.—In forward motion until steam is properly regulated through watching the open cylinder cocks, then the reverse lever should be immediately placed a few notches back of the center, as desired.

Question 5.—Should cylinder cocks be open or closed?

Answer 5.—They should be left open.

Question 6.—Explain how the water brake is then applied and released.

Answer 6.—By the opening and closing of the water valve and the movement of the lever to reverse or to forward motion.

Question 7.—How can you tell when water brake valve is opened sufficiently?

Answer 7.—By the color of the steam as it escapes from the cylinder cocks before reversing.

Question 8.—How is the power of the water brake regulated?

Answer 8.—By hooking the reverse lever farther back in the quadrant it is increased, and vice versa.

Question 9.—At what speed is the water brake most efficient?

Answer 9.—At from 5 to 12 miles per hour.

Question 10.—What speed should not be exceeded when water brake is put into operation?

Answer 10.—Not more than 16 to 18 miles per hour.

TRAIN AIR SIGNAL.

Question 1.—How does the air signal equipment operate?

Answer 1.—Air pressure from the main reservoir is supplied at a reduced pressure through the reducing valve to the signal line. On each car a branch of the signal line leads through a cut-out cock to the signal discharge valve above the door; a branch on the locomotive leads to the whistle valve. Any sudden reduction in the signal line releases the whistle valve and blows the whistle.

Question 2.—What pressure should be carried in the signal line? How do you know you have this pressure?

Answer 2.—Forty pounds. By a test gauge or by placing the brake valve in full release, shut off the pump and open the rear train line cock until the whistle blows; then the red pointer of gauge shows the signal line pressure approximately.

Question 3.—What causes the signal whistle to blow each time the brake is released?

Answer 3.—Dirty reducing valve which lets full main drum pressure accumulate in the signal pipe and when the brake is released, the flow of air from the signal pipe back to the main reservoir blows the whistle.

Question 4.—If the whistle gives a weak blast where would you look for the trouble?

Answer 4.—First see that the whistle was clean and properly adjusted; next see if opening the rear signal cock on the engine a little would give good whistle; if not the whistle valve or pipe may be stopped up. If the apparatus on the engine is all right, the car discharge valve or strainer may be stopped up or a very bad leak exist in the signal line on the train.

Question 5.—What makes it repeat the signal?

Answer 5.—Too short and quick an opening of the discharge valve in the middle of a long train sometimes, or the whistle valve stem not fitting properly.

Question 6.—Will a leak in the signal line affect the working of the signal valve? Explain.

Answer 6.—Yes. You can give signals from cars ahead of the leak better and in more quick succession than from cars back of the leak. A continuous leak keeps the reducing valve open all the time, hence to blow the whistle you have to reduce the signal line pressure faster than it is being supplied, which is difficult on a long train especially.

Question 7.—Where will you look for trouble if the signal pipe does not charge?

Answer 7.—In the reducing valve. It may be dirty, the adjusting spring not set, or the signal cut out cock closed at the reducer connection.

AIR BRAKE—MISCELLANEOUS.

Question 1.—Trace the air through the air brake system.

Answer 1.—The air is received from the atmosphere through the air cylinder of the pump; from there is passes through the discharge valve and pipe to the main reservoir; thence through the brake valve to the train pipe; through the branch pipe, cut out cock and triple valve to the auxiliary reservoir (to charge); then from the auxiliary through the triple valve to the brake cylinder (to set the brake), from the cylinder again back through the triple to the atmosphere (to release the brake). When a retainer is used, the final exhaust from the triple has to pass through the retaining valve.

Question 2.—Should the engine equipment be tested before leaving the engine house?

Answer 2.—It certainly should and be known to be in good working order.

Question 3.—How should this test be made?

Answer 3.—Open the bleed cocks in main and auxiliary reservoirs, start the pump slowly, lubricate it properly, observe about the number of strokes required to compress from 40 to 50 pounds, open the rear and front signal and train line cocks to see that they are working and not frozen, see that the governor and the feed-valve are properly regulating the pressures and that the pump stops working, indicating no leaks; then apply a service application and see that the brakes remain set at least three minutes and that the pistons have proper travel; release and see that they release all right.

Question 4.—What is your first duty after coupling onto a train?

Answer 4.—Charge the train fully and see that the trainmen fix any leaks.

Question 5.—Should the brakes be tested before leaving a terminal?

Answer 5.—Always.

Question 6.—How should this terminal test be made? Explain in detail, giving trainmen's duties also.

Answer 6.—Beginning at the rear, the brakeman should couple all the hose, open all the angle cocks except the one at the rear, see that all the cars are cut in (except such as are marked defective), see that all the hand brakes are off,

and the retainers open, with the handles pointing down. The engine should be cut in last. While the engine is charging the cars, the brakemen should pass along the train and inspect it carefully to ascertain if there are any leaks. In charging a train the pump should be run according to the temperature of the weather, in order to charge the train reasonably fast without overheating it. Where there are average leaks, an eight inch pump should charge a train in about one-half as many minutes as there are cars; a nine-and-one-half inch pump twice as quickly. After the train is charged and the engineer is satisfied that it is reasonably free from leaks, the head brakeman (stationed at the head air brake car) should signal the rear brakeman (stationed at the rear air brake car) who should repeat the signal. After the engineer gets the signal from the rear man, he should apply fifteen to eighteen pounds in service application and place the engineer's valve handle on lap. The brakemen should now walk toward each other, inspecting each car, to see that it sets and holds—noting the piston travel as well. After this has been done, they should signal the engineer to release. He having done so in release position, the brakemen should pass each to his respective end of the air brake cars to see that all the brakes have been released, and, in winter, see that no shoes are frozen to the wheels. The head brakeman should then advise the engineer as to the number of air cars that are in good working order, and the tonnage or length of the train.

Question 7.—Why is a terminal test necessary? Or, is it only advisable?

Answer 7.—It is necessary to insure the safety and celerity of a train on the road.

Question 8.—What test is necessary after coupling up, when air brake cars have been separated for a crossing, or make-up of train changed?

Answer 8.—To know by trial that the engineer can set and release the rear cars in the train. If the make-up of the train has been changed and any cars added; besides noticing the rear cars, a regular terminal test should be given the cars just picked up.

Question 9.—What is meant by a running test? How and where is this test made?

Answer 9.—A test of the air brakes while the train is moving. It is good practice to make a running test of the brakes at the summit of heavy grades, also two miles from important points, meeting points, railroad crossings, etc. On passenger trains a sufficient reduction (8 to 10 pounds) should be made to feel the brakes holding well, also noticing the length of the blow from the train line exhaust. On long freight trains, releasing brakes while moving is such poor

practice that it is generally better to make only a three or four pound reduction for a running test, determining the length of the train from the train line exhaust.

Question 10.—What is the leakage grpove in the brake cylinder for?

Answer 10.—To allow the air to pass by the piston and not set the brake when the train pipe pressure is reduced slowly by ordinary leakage. This groove is long enough so that the piston has to travel over 3 inches to cover it and is in the back end of all cylinders except driver brakes.

Question 11.—In making a service application, wha• should the first reduction be? Explain why.

Answer 11.—From 5 to 8 pounds, sufficient to get all pistons by the leakage grooves. With 10 to 15 cars, 5 pounds would do this, with 50 to 60 cars, 8 pounds would be necessary.

Question 12.—Does a long train require a heavier reduction than a short train? Why?

Answer 12.—Yes, because the train line exhaust opening is the same size for all length trains, hence the longer the train, the slower the reduction in train pipe pressure and the slower the pistons move past their leakage grooves; unless the reduction is continued until each piston passes the leakage groove, that brake will not apply in making the stop, or if it does set later it will be with a less pressure.

Question 13.—From a seventy-pound train pipe pressure, how much of a reduction will be required to apply the brakes in full?

Answer 13.—From 18 to 20 pounds with an 8 inch piston travel—the greater reduction on long trains on account of more loss at the leakage grooves.

Question 14.—Has the piston travel anything to do with the pressure obtained in the brake cylinder?

Answer 14.—Yes, the shorter the travel (if beyond the leakage groove) the greater the pressure, as the space to fill is so much smaller.

Question 15.—With proper pressure and proper piston travel what is the brake cylinder pressure with a full service application? With an emergency application?

Answer 15.—About 50 pounds in service; about 60 pounds in emergency with the quick action triple.

Question 16.—Is there any difference in these brake cylinder pressures with different forms of triples?

Answer 16.—Yes, with the plain triple there is no greater pressure in the cylinder from emergency than from service application.

Question 17.—How should you apply and release the brakes on a part air-braked freight train? How on a very long all-air train?

Answer 17.—Shut off and let all the slack that will run in, then make the first application as per answer No. 11 above. Increase the application as necessary. To release this part air train if necessary while moving, let off a few brakes at a time by placing the brake valve in running position a second and back to lap several times in slow succession; when you think they are all off, to full release, then running position and let the slack run out before carefully working steam. With a very long all-air train it is practically impossible to jerk the train no matter how you apply the brakes in service. First reduce 8 or 9 pounds, then 10 to 15 more as is necessary to stop. If avoidable, do not release *at all* when moving or you will likely break the train in two, especially when moving very slowly. If necessary to release at the foot of a grade, do so while the rear part of train is still on the hill. If you have an independent or straight air brake on the engine, keep it set tight until the train brakes are all released.

Question 18.—How would you make a two-application stop with a passenger train?

Answer 18.—If fast time is to be made, run fast up near the station, apply 10 to 15 or even 20 pounds in service, when the train is down to about 15 to 20 miles per hour speed, release in full release and back to lap; then apply with two or three 5 pound reductions, as necessary to stop right.*

Question 19.—How and when would you release the brakes on a short passenger train? On a long passenger train (over ten cars)?

Answer 19.—Release the brakes on a short passenger train just 5 or 6 feet before stopping; on a very long passenger train, release 10 or 12 feet before stopping. More depends upon how much pressure you have in the brake cylinders than on the length of train. Try to release just as early as you can and still not let the train run along.

Question 20.—How and when would you release the brakes on a short freight? How on a long freight train?

Answer 20.—Not until the full stop is made on any length freight train, if it can be avoided. See answer to No. 17.

Question 21.—How should a stop at a water tank or coal chute be made with a long freight train?

Answer 21.—Stop a few car lengths short; cut off the engine to take coal or water.

Question 22.—In switching with an air brake train and picking up uncharged cars, how should you handle engineer's valve?

Answer 22.—A high main reservoir pressure will release a low auxiliary pressure; hence before coupling to the uncharged cars see that this condition exists even if you have to set

*A more comprehensive answer to Question 18 will be found on page 478.

and release the brakes (without recharging) you have coupled to the engine. When coupled up, the handle on lap and a high excess pressure, you will be able to release and move at once. Leave the valve in full release until the guage hands begin to rise.

Question 23.—When applying the brakes in service, can you detect if any brake sets quick action? Explain.

Answer 23.—If standing, by the train line exhaust; if moving, also by the jerking of the train. If the exhaust from the train line stops suddenly while the valve is in service application position (it may or may not start again according to how much reduction is made), it shows that the train pipe pressure has dropped faster and lower than the pressure in Chamber "D." Emergency does this by venting part of the train pipe pressure directly to the brake cylinders.

Question 24.—If one quick action triple goes into emergency, will the others follow? How will you locate this defective triple?

Answer 24.—Yes, if it is a quick action triple, all the other triples of either kind will go to emergency. Rare exceptions to this rule may occur where a large number of plain triples or cars having brakes cut out are placed together in a train. One method is to set about five pounds in service application and then find out which cars having quick action triple valves have not set; have some one watch each car while increasing three to five pounds more in the service application. The car that sets in quick action first is the defective one, but as emergency travels at the rate of about twenty-three cars per second, it is best to cut out one of the cars that did not set at the first reduction, and have the application continued; if this proved not to have been the one thus defective, test the train again, cutting out another car that failed on the first application, until the defective car is located. Another and ordinarily shorter method is as follows: Cut the air cars in two equal sections and repeat the test for trying brakes. This will tell which half of the train is defective. Then take one-quarter or three-quarters, according to whether the defective car is in the front half or back half of the train, and continue in this way (never trying with less than three car lengths of piping) until the defective car is found and cut out A broken graduating pin in the quick action triple or a sticky triple piston will cause a brake to set quick action, and although this rarely occurs, no train should be taken out of the station until the defective car is located and cut out. It should be done before damage occurs.

Question 25.—Should the brakes be relased before uncoupling from train? Why?

Answer 25.—Yes, in order that the cars can be switched

and the car repairers can tap (test) the wheels or jack up a journal box; also to prevent shoes from freezing to the wheels, and especially because a brake that is applied leaks so rapidly that in changing engines it may be found that much of the air has escaped.

Question 26.—In descending a grade how can you best keep a train under control?

Answer 26.—The best way is to apply the air lightly while the train is moving slowly keep the train at a slow speed and the train-line pressure as high as possible all the time. To do this, if it is necessary to recharge, reduce the speed below the average just before recharging. To recharge, handle the train as though a flagman had been seen half a mile ahead, that is, go slowly and exercise caution.

Question 27.—In what position would you carry the brake valve handle between applications of the brake while descending a grade? Why?

Answer 27.—Full release up to the standard train line pressure, because you can thus charge up the more quickly.

Question 28.—How rapidly does an auxiliary charge from fifty to seventy pounds? When should you bear this in mind particularly?

Answer 28.—About half a pound a second. In making a second application soon after having released.

Question 29.—Explain the operation of the pressure retaining valve. What is its use?

Answer 29.—It is a weighted valve which the triple exhaust from the cylinder has to raise in order to escape, when the handle is turned up, before the brake is released. It causes the release to be slower and finally holds from 15 to 20 pounds pressure in the brake cylinder while the auxiliary reservoir is being recharged.

Question 30.—How many pounds of air is it intended to close up on, and hold in the brake cylinder?

Answer 30.—15 to 20 pounds.

Question 31.—Does the brake release any slower until it gets down to this pressure?

Answer 31.—Yes, see answer 29.

Question 32.—Name the defects which cause the retaining valve to be ineffective.

Answer 32.—Dirt under valve, cock leaking, retainer pipe leaking.

Question 33.—How do you make a test of retaining valves?

Answer 33.—Reduce 10 to 15 pounds train line and then release with the retainers turned up. The retainer should hold the brake set at least two minutes.

Question 34.—When brakes go on suddenly without the action of the engineer, what are the causes. And what should you do?

Answer 34.—The train has parted, a hose has burst or a valve has been pulled open. Shut off at once under all circumstances and place the brake valve on lap as quickly as possible.

Question 35.—If you found the train was broken in two, how would you proceed to get under way again promptly?

Answer 35.—When the train has been brought to a stop, I would place the handle in running position to see if the train pipe is still open. If I thought it was a burst hose, I would keep the handle moving from lap to running position and back, so that the trainmen could hear the air escaping from the burst hose. If I find that the black hand is gaining in running position, I would know that the trainmen had found the defect and had closed the angle cock ahead of it. I would then release the head brakes and lap the valve so as to pump up excess ready to release the rear cars when the hose had been replaced, or the train recoupled if it had been parted.

Question 36.—How would you proceed in case of bursted hose? How can you help trainmen to locate it?

Answer 36.—By occasionally throwing the brake valve to release and back to lap.

Question 37.—Why is it dangerous to apply and release the brakes repeatedly on grades, and at station stops?

Answer 37.—If the auxiliary reservoirs are not given time to recharge between applications, there will not be sufficient pressure left with which to make a stop.

Question 38.—When two or more engines are coupled together, which engineman should do the braking? What should the other engineman do?

Answer 38.—The head engineman. Close the cut out cock underneath each brake valve, except the head one, place the valve in running position and keep the pump running in case of necessity.

Question 39.—Why is it important to have driver brakes in good order?

Answer 39.—Because they are the most powerful brakes on the train, are used the most, keep the tires worn down and prevent the engine from pulling away from the tank or train.

Question 40.—How would you test for leaks in driver brakes?

Answer 40.—Make four 5 pound reductions (and see that they apply with the first) and they should remain set at least three minutes. If not, set fully or in "straight air" and examine with a torch all joints and pipes from the triple valve to both cylinders and all parts of the latter.

Question 41.—Would you reverse an engine with the driver brakes applied? Why?

Answer 41.—Not if the brakes were in good order; because it would slide the wheels and not stop as quickly.

Question 42.—What is the proper piston travel for engine brakes? For tender brakes? For car brakes? Explain how each is adjusted?

Answer 42.—Generally speaking the piston travel should be kept between one-half to three-fourths the length of all kinds of brake cylinders except drivers. It is advisable, however, that freight cars be taken up to five inches when empty and drivers are best kept between two and four inches. It occurs in the practice of some companies, that engine trucks and ore cars or other cars of special construction have cylinders but eight inches long. In passenger cars the slack is taken up by the turn-buckles or dead levers. In freight cars and tenders it is taken up by the dead levers, or bottom rods for inside connected brakes. In cam driver brakes, it is taken up by lengthening the arms, and in truck brakes by lengthening the outside arms.

Question 43.—What is the percentage of braking power on an engine? A tender? A passenger car? A freight car?

Answer 43.—About 70%; 100% of its weight without coal or water; 90% passenger and about 70% for empty freight cars.

Question 44.—Do you consider a good light on the air gauge as important as on the steam gauge? How often and at what places should you look at the air gauge?

Answer 44.—Yes, more so, as steam is indicated by the working of the engine while, until ready for its use, there is no certain indication of the amount of air pressure except by the gauge, which must be clearly seen. Clear vision of the air gauge at night is very important and should be given proper attention; the light from the fire-box when the door is open is not sufficient. When whistling for road crossings, or other similar places, and about two miles from all dangerous places or places where the train is to stop, the gauge should be examined particularly.

Question 45.—Do you appreciate the fact that handling the air brakes is a task requiring skill and close attention, to insure the comfort of passengers and the safety of freight and cars?

Answer 45.—I do.

Question 46.—Do you understand that a failure of air brakes to work is invariably due to the failure of some man to do the proper thing at the proper time?

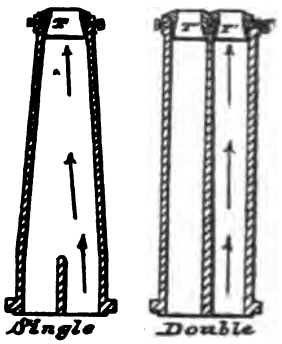
Answer 46.—I do.

Question 47.—Do you understand that all brakes must be kept in good order to give proper service, and that proper reports of their condition must be made by men operating them to insure their maintenance.

Answer 47.—I do.

The exhaust pipe, as its name implies, is a pipe for carrying the exhaust steam from the cylinders to the smoke-box of the engine and so through the smokestack. Suitably attached to the upper end of the exhaust pipe is the exhaust tip or nozzle, the size of which is altered in accordance with the draught requirements of the engine—a small exhaust creates a powerful draught, and *vice versa*. (See Figs. 2 and 3.) The steam is carried to the smokestack for the purpose of creating a forced draught through the fire-box.

Fig. 2. Fig. 3.



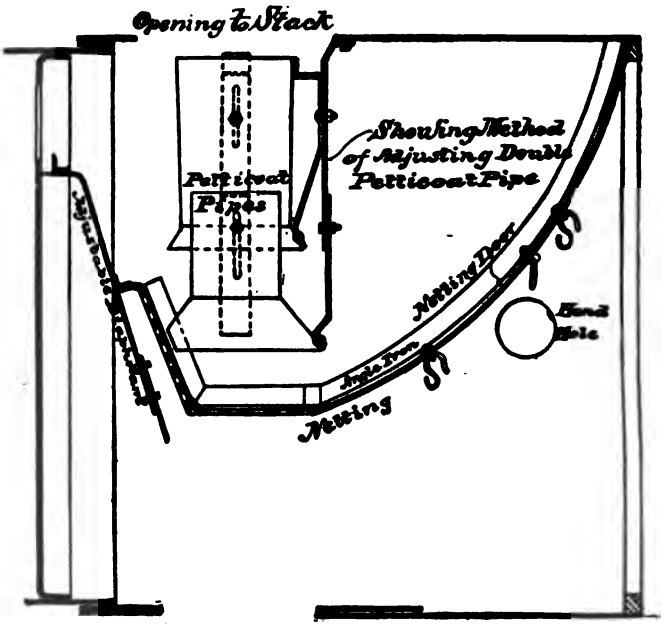


Fig. 4.
Draught Appliances in Smoke Box

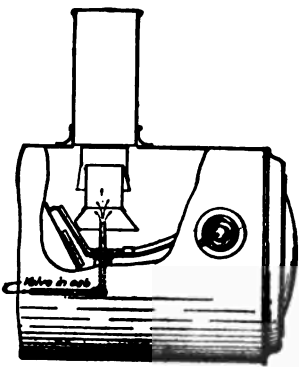


FIG. 5.
Blower.

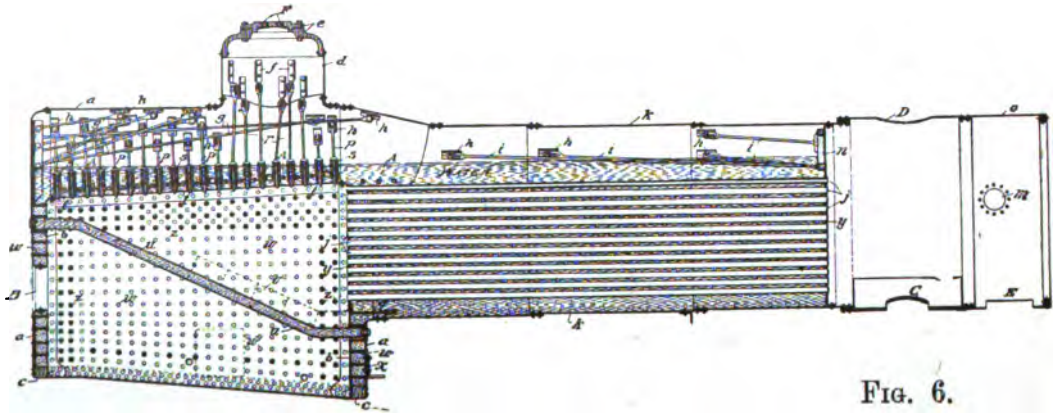


FIG. 6.

Longitudinal Section of Locomotive Boiler Filled With Water.

a Boiler shell. *b* Inside shell of fire box. *c* Mud ring. *d* Dome shell. *e* Dome castings. *f* Dome lugs. *g* Rear longitudinal stays. *h* Shell lugs. *i* Forward longitudinal stays. *j* Flues. *k* Barrel Plates. *m* Hand hole. *n* Dry pipe ring, *o* Extension end. *p* Sling stays. *q* Inside shell brace, *r* Dome sling stays. *s* Crown-bars. *t* Crown-sheet. *u* Water tubes for supporting arch. *v* Brick arch. *w* Stay bolts (solid). *x* Frame tie. *y* Flue sheets. *z* Stay bolts (hollow). *A* Cross stays. *B* Fire door. *C* Saddle opening. *D* Smokestack opening. *E* Cinder chute opening. *F* Safety-valve connections.

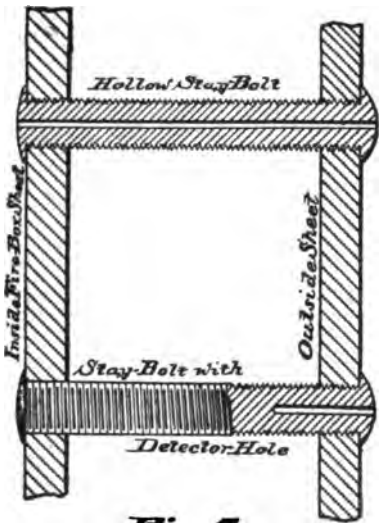


Fig. 7.
Stay Bolts.

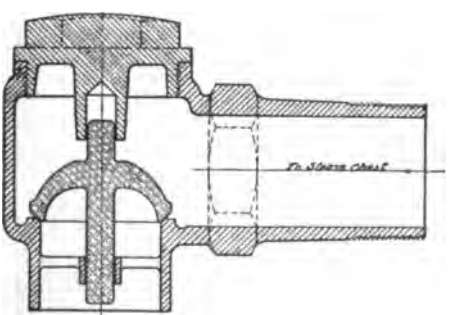


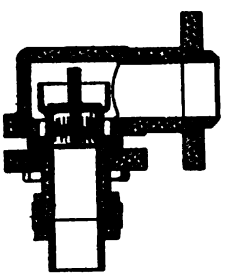
Fig. 8.
—Steam Chest Relief Valve—

Fig. 9.

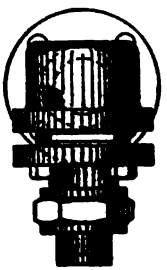
Wedge Made of Hardwood—4x4", 8 long.

For Use in Case of Broken Spring or Hanger, Tire or Axle, Equalizer, &c.

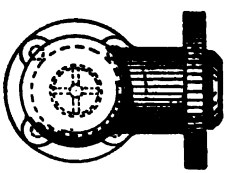
One of These Should be on Every Engine



Section



Elevation.

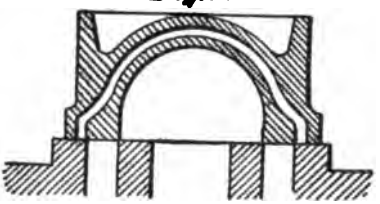


Plan.

FIG. 9A.

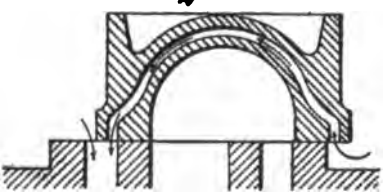
Check valve, for preventing water from running.

Fig. 10.



Allen Ported Valve
Central Position

Fig. 11.



Allen Valve
Early Admission Period

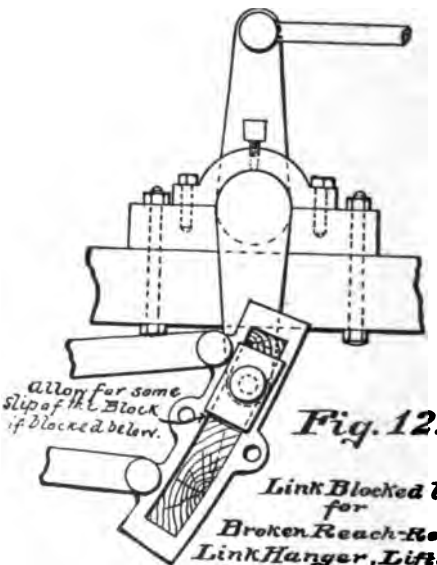
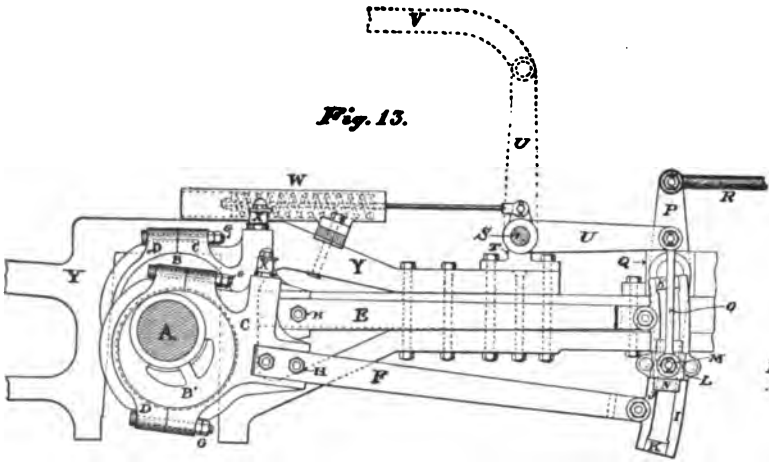


Fig. 12.

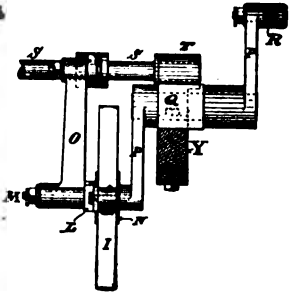
Link Blocked Up for Broken Reach-Rod, Link Hanger, Lifter, or Saddle Pin.

Fig. 13.



SIDE VIEW.

Fig. 14.



END VIEW.

ECCENTRICS, STRAPS AND REVERSING GEAR.

A—Axle.
BB'—Eccentrics.
CC—Front half of eccentric-strap.
DD—Back half of eccentric-strap.
E—Forward motion eccentric-rod.
F—Back motion eccentric-rod.
GG—Eccentric-strap bolts.
HH—Eccentric-rod bolts.
I—Reversing-link, front half.
J—Reversing-link, back half.
KK—Reversing-link filling pieces.
L—Reversing-link saddle.
M—Saddle pin.
N—Link-block.
O—Link-lifter.
PP—Rocker-arms.
Q—Rocker-shaft box.
R—Valve rod.
S—Reversing or tumbling shaft.
T—Reversing shaft box.
U—Reversing-arms.
V—Reach-rod.
W—Spring counter-balance.
XX—Eccentric oil-cups.
Y—Frame of engine.

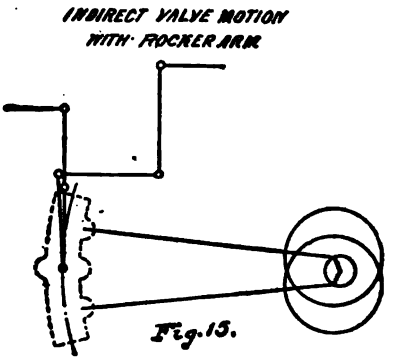


Fig. 13.

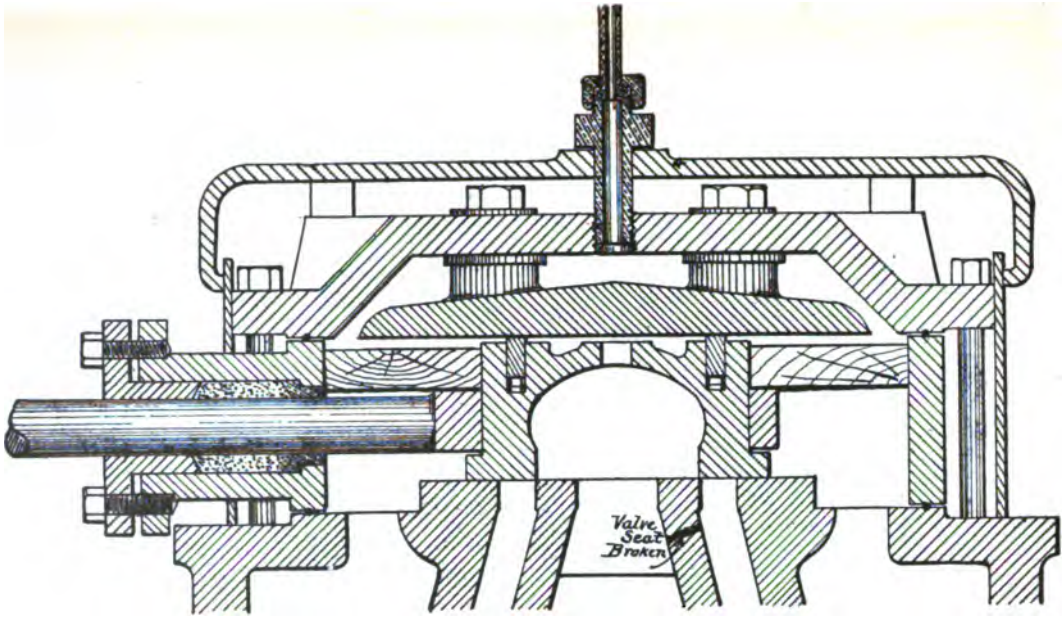
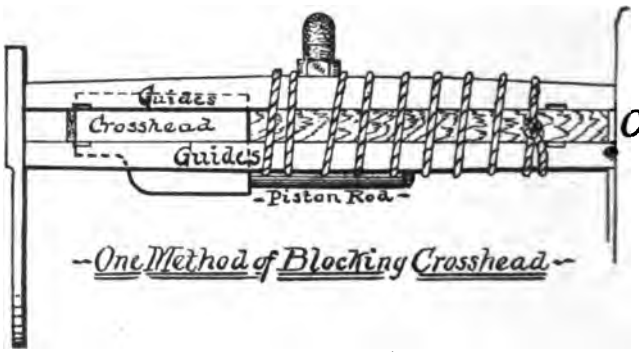


Fig. 16.

Richardson Balanced Slide Valve

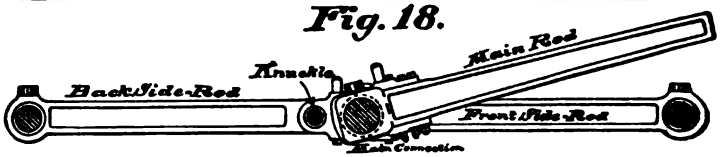
Also showing Method of Blocking any Slide Valve for Broken Valve Seat or Other Breaks Inside of the Steam Chest.

Fig. 17.



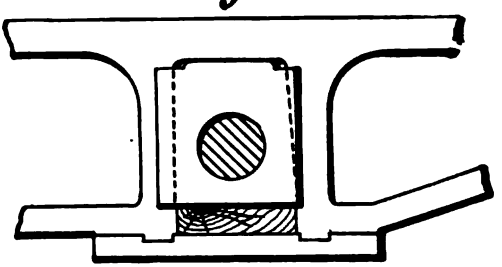
One Method of Blocking Crosshead

Fig. 18.



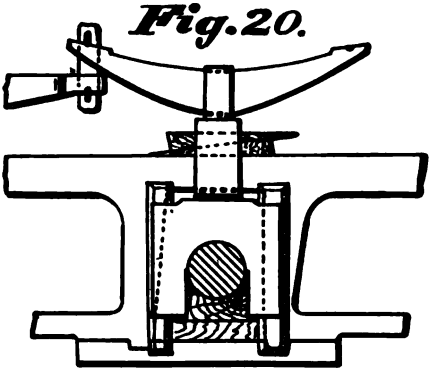
Rods &c.
For Rigid or Ten-Wheel Engine

Fig. 19.



Wheel Blocked Up
For Broken Tire or Axle

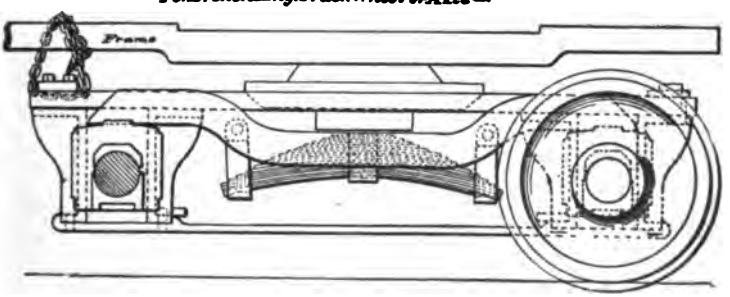
Fig. 20.



~~ Driving Axle Broken Outside the Box ~~

Fig. 21.

~~ An Broken Engine Truck Wheel or Axle ~~



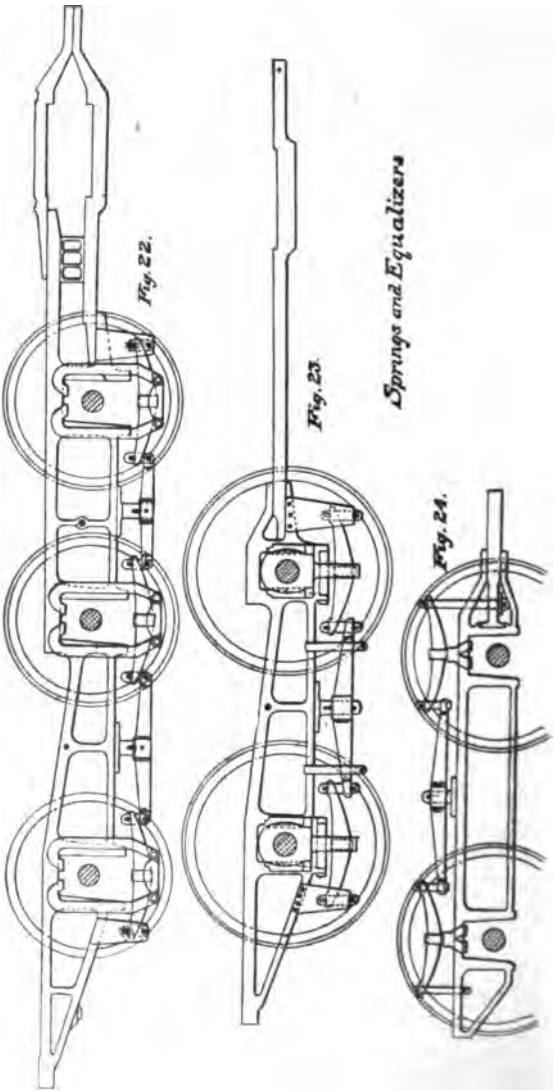


Fig. 22.
Fig. 23.
Springs and Equalizers
Fig. 24.

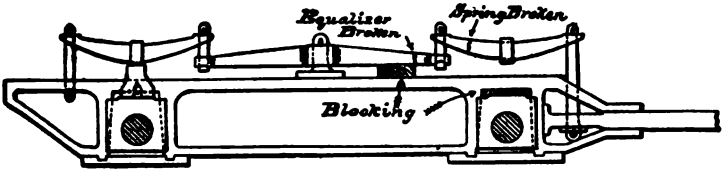
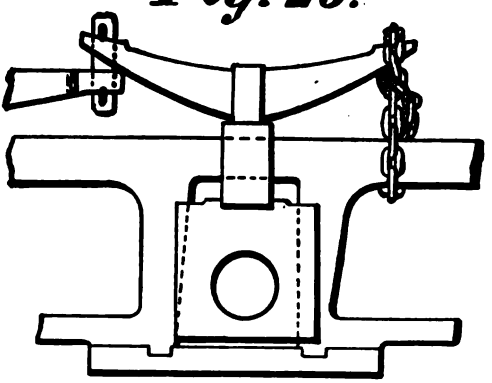


Fig. 25.

Blocking for Broken Driver Springs.

Fig. 26.



~Broken Hanger Replaced by a Chain~

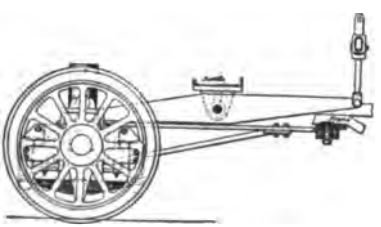
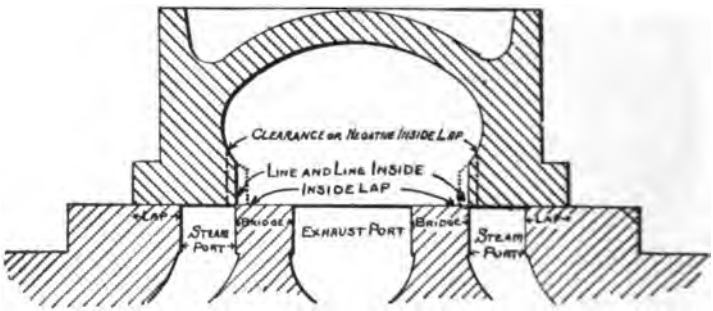


Fig. 26[A].

Side View of American Bogie (or Pony) Truck, supporting forward end of locomotive.

Fig. 27.



Graphic Definitions of Valve Dimensions.

For the purpose of particularizing the various positions of the driving wheel crank (when occasion requires), the 360 degrees through which it passes are divided into eight parts; the "upper quarter" represents the crank pin when directly above the main axle; the "lower quarter" when directly below it; the "forward center" locates the crank pin on a straight line between the main axle and the cylinder, the "back center" 180 degrees from there. The "eights" are the upper, lower, forward and back, as shown by diagram.

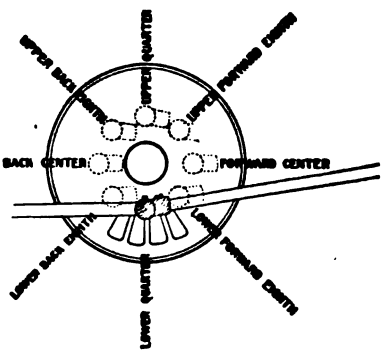


FIG. 28.

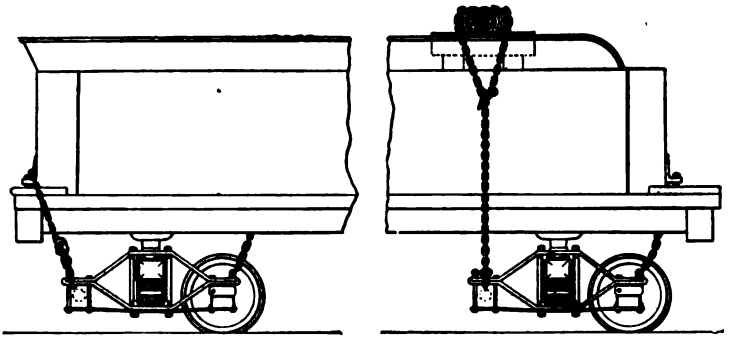


Fig. 29. *Fig. 30.*

— Two Methods of Chaining up Truck for Broken Wheel or Axle —

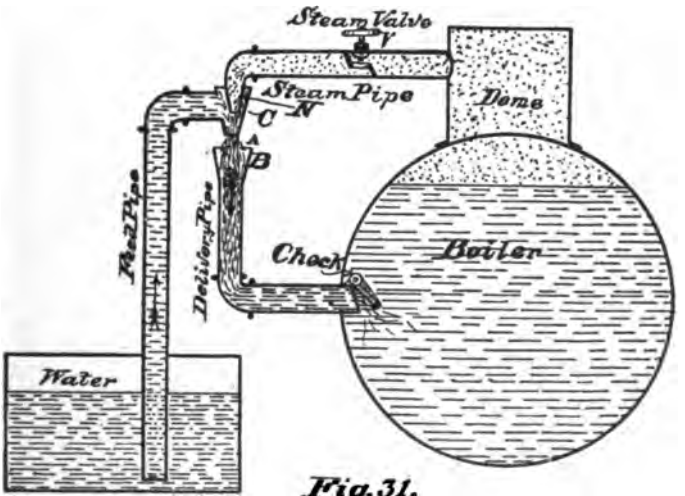


Fig. 31.
Injector Principle

Question 18.—How would you make a two-application stop with a passenger train?

Answer 18.—With A-1 equipment on engines (not E. T.) standard quick action brakes on train, if fast time is to be made run fast up near the station, apply 15 to 20 pounds with a rapid split reduction in service, when the train is down to about 15 miles per hour speed, release in full release position, making sure all triple valves are moved to release, then move back to lap; then apply with two or three light reductions as necessary to stop right.

When the engine has E. T. a pause of two or three seconds should be made on running position; that is, after release pause on running position just before taking lap position or beginning the second application. This is to allow the engine brake to release with the train brakes after the first application. Where time will permit brake valve should be placed on running position after release, to take advantage of recharging and equalizing all pressures before the second application. Beginning second application it is well to reduce chamber "D" till the brake pipe begins to blow; this causes prompt response when balance of reductions occur.

Where the train has complete L. N. & P. C. equipment with graduated release available, make the 15 or 20 pounds, or even 25 pounds split reduction at high speed, when the train has slowed down considerable, place the brake valve in running position and back on lap to graduate the brakes off, repeat this till the final part of stop, finishing the stop with only a light cylinder pressure remaining on the whole train. This is virtually only one application, graduated off to low cylinder pressure at final part of stop. In graduating off the brake valve should be held in running position a little longer for long trains than short trains; also the first time to running position should be slightly longer than the succeeding times. It is not intended to graduate off more than three times. Do not graduate off on less than a 10-pound brake pipe reduction. Any time after graduating off, if a further application is needed, the brakes will respond immediately with light reduction.

NOTE: A split reduction means to apply 7 or 8 pounds, wait till the brake pipe ceases to blow, then immediately follow with the balance to complete fast-application reduction. This is done to favor the slack action in the train.

CHAPTER XIII.

HOW OIL IS USED FOR FUEL ON LOCOMOTIVES.

WHAT FUEL OIL IS AND HOW OBTAINED.

Fuel oil, as it is commonly called in America, is known to the commerce of the world as Petroleum, a word coined from two latin terms *petra* a rock and *oleum* oil, and which accurately describes the liquid which is found in the earth naturally in many parts of the globe and is believed to be formed by the gradual decomposition of vegetable matter beneath the surface.

The oil varies much in color and consistency in different localities. In some places it is of a faint yellow color thin and almost transparent; in others of a brownish black color sometimes as thick as molasses. It is found in most European countries and in the United States; it has been for many years abundant in Pennsylvania, New York, Ohio and Indiana, and latterly has been found in large quantities in the States of California and Texas.

Generally speaking, the oil is brought to the surface by means of pumping from wells; in some instances, however, the supply is so abundant that the wells have a natural flow; sometimes also it is found oozing from the crevices of rocks or floating on the surface of water.

The existence of petroleum has been known in the states of New York and Pennsylvania from

the earliest Colonial days. It was not till the year 1859, however, that it began to be of commercial importance in America; in that year wells began to be systematically bored. The product of the oil fields of New York and Pennsylvania has been and is, utilized principally as an illuminant, the crude oil being for that purpose refined and marketed in the form of Kerosene. This industry has grown to enormous proportions, not only supplying America with sufficient for home consumption, but exporting a vast quantity annually to all parts of the world.

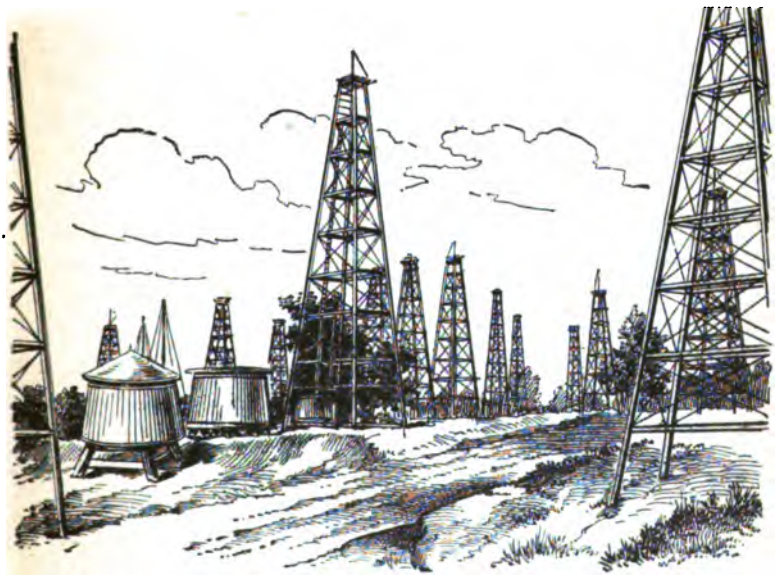


FIG. 1.

OIL FIELDS.

THE USE OF OIL AS FUEL—ITS ADVANTAGES UNDER FAVORABLE CONDITIONS.

The use of oil as fuel is no new thing; it can be traced to the times of remote antiquity. Its scientific adoption to industrial purposes commenced, however, not earlier than about the year 1860. In 1870 it was used during the great siege of Paris in France when the city's supply of coal had been exhausted and we are told it was the means of enabling the city to keep several of its large factories going and to grind its flour by steam while it was begirt by its enemies.

Conditions will have to change very much before oil can come into general use as fuel for industrial purposes by reason of its greater cost at present as compared with that universal fuel, coal. In favored countries or districts, however, where the supply is plenteous and close at hand, or where coal is more remote and the difficulty of cost does not stand in the way of its economical use, it seems certain that oil will be more and more used because the mechanical difficulties attending its use are one by one being overcome. More than a decade ago in the Caspian region where petroleum is plentiful the apparatus for its consumption had been measurably perfected and oil for fuel had replaced wood and coal on all the steamers plying on the Caspian Sea and on the locomotives of the Trans-Caucasian Railway as well as in the furnaces and factories of that district.

With the discovery of new sources of oil supply in America its availability as fuel on loco-

motives has become general in certain districts, and it is not unreasonable to suppose that further supplies will be found and the field for its use be correspondingly enlarged, so that the subject has become, and will be in the future, of great interest to those concerned with the motive power of our railroads.*

Petroleum as a fuel for locomotives is said, apart from the economic question of cost, to be infinitely superior to coal: It is smokeless; free from dirt and dust; can be instantly lighted; requires no stoking; can be regulated instantly and easily; requires much less storage room, and its calorific power for purposes of generating steam is several times greater than that of ordinary coal. There are, in fact, many things to be said in its favor for this purpose but few against it: While it is true that its use reduces the life of the flues and firebox about twenty-five per cent yet, on the other hand, it emits no sparks to cause conflagrations along the right of way or set fire to stations, buildings, or equipment; the cost of handling it is at least seventy-five per cent less than coal; no clinkers have to be removed at terminals or on the road; its use reduces the time consumed in turning the engine; it makes no refuse or cinders to be taken care of; it insures freer steaming and freer running loco-

*In the United States it is said that oil for locomotive fuel at $1.00 per barrel is an economical equivalent of coal at $4.00 per ton. At some points where oil is now obtainable at the price mentioned coal costs from $7.00 to $8.00 per ton. Its great economic value under such circumstances is apparent.

motives and consequently affords greater ability to handle maximum loads; furnishing a uniform grade of fuel, it becomes practicable to adjust draft appliances so as to get the best results under all conditions; owing to the easy and exact regulation of the fire possible, the greatest economy in firing is possible, as the labor of firing coal conduces to extravagance in its use; and, finally, the fuel supply can be taken at stations simultaneously with water very rapidly and without waste.

STORAGE.

In the practical operation of railways, after the oil has been taken from the earth it is necessary to store it in reservoirs from which it is conveyed to supply or delivery tanks; an illustration showing the kind of tanks used and their location in relation to the water supply is shown in Fig. 2.

These supply tanks are often located opposite the water tanks so that fuel and water can be taken simultaneously. In the construction of these tanks it is generally necessary to make provision for heating their contents so as to insure the oil flowing freely in cold weather. The accompanying illustration (Fig. 3) shows the details of the construction of a supply or delivery tank.

SPECIAL ADAPTATION OF LOCOMOTIVES—THE TENDER.

Locomotives on which oil is used for fuel must be specially adapted for the purpose. From the

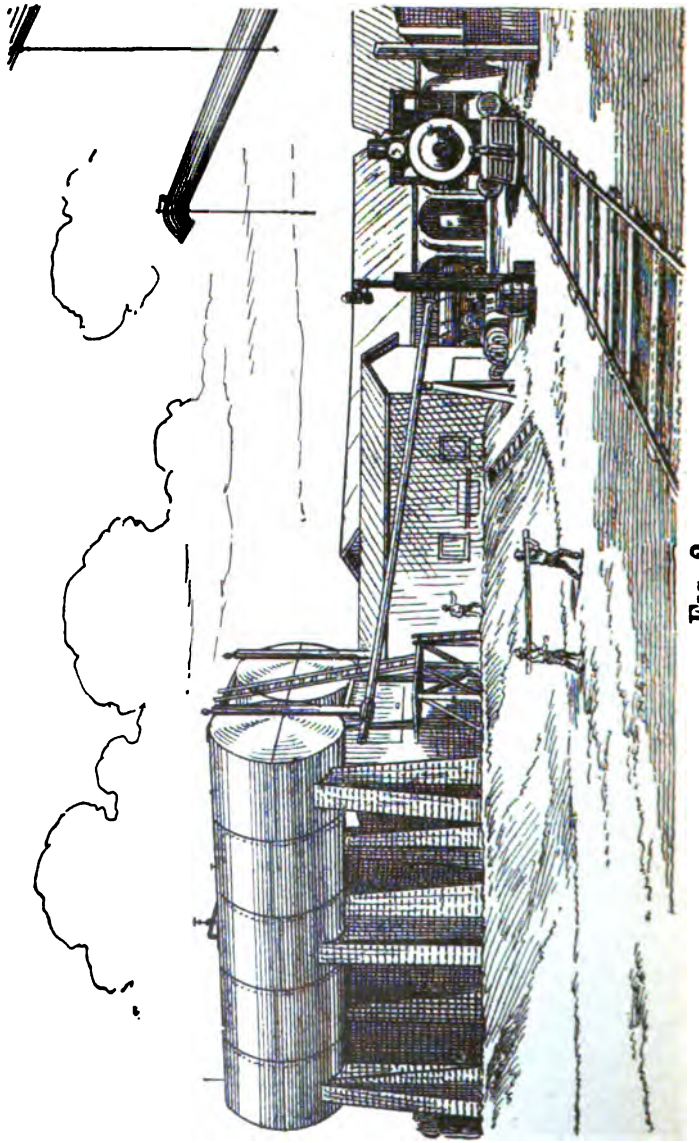


FIG. 2.
OIL AND WATER STATION.

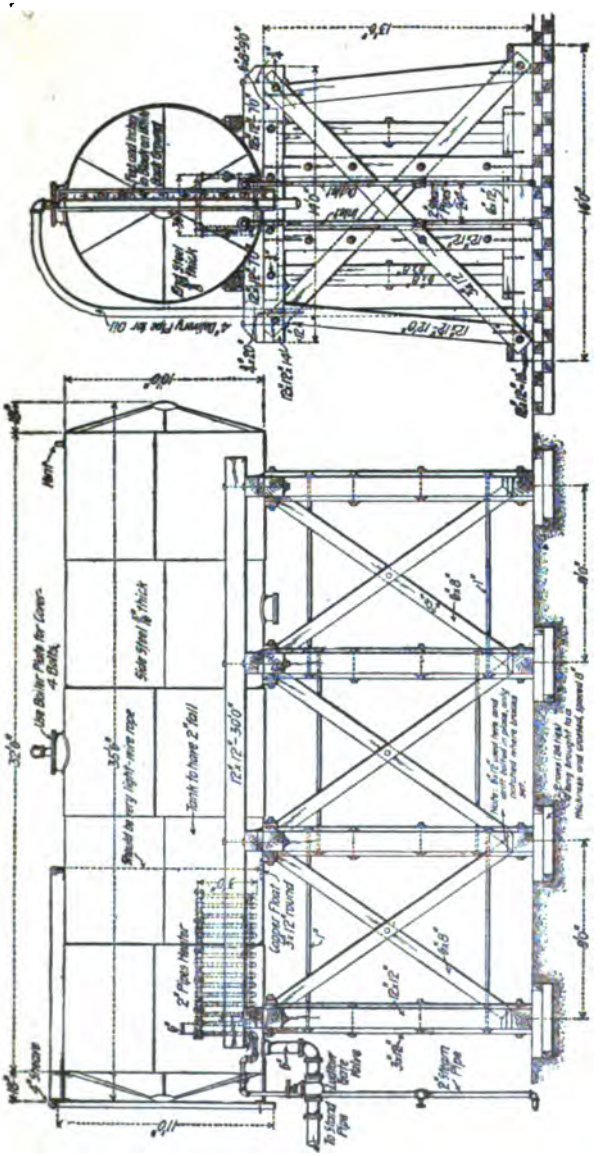


FIG. 3.

DETAILS OF CONSTRUCTION OF SUPPLY OR DELIVERY TANK.

delivery or supply tank the oil is conveyed to a tank in the tender which is generally a separate receptacle fitted in the space ordinarily used for coal. The arrangement of the tender is indicated in the following illustrations. Figure 4 shows the outside appearance of a tender equipped for oil burning.

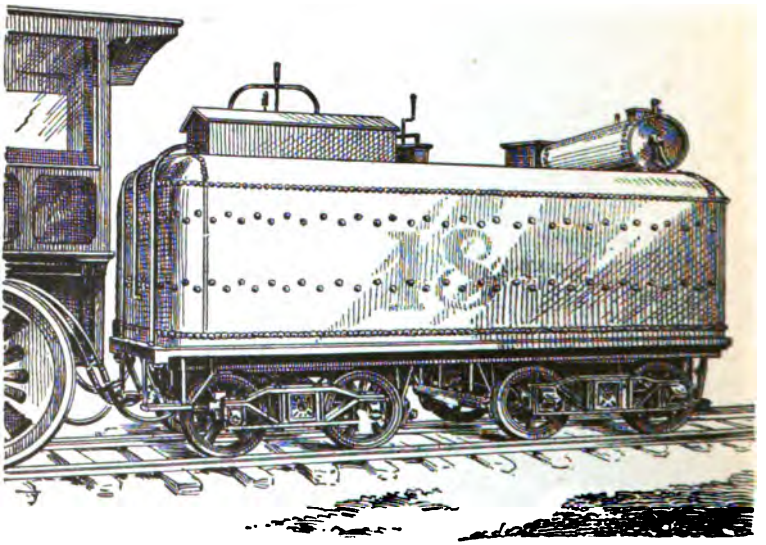


FIG. 4.

APPEARANCE OF TENDER EQUIPPED FOR OIL BURNING.

Figure 5 shows the details of the tender equipment as used on the Southern Pacific Railway.

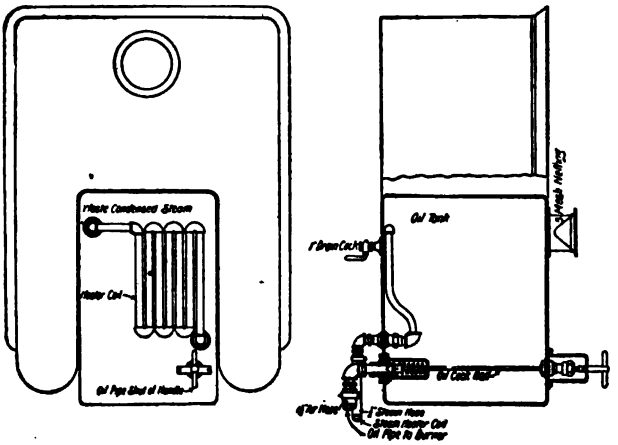


FIG. 5.

DETAILS OF TENDER EQUIPMENT—SOUTHERN PACIFIC.

THE HEATER COIL IN TENDER.

As in the case of the supply or delivery tank so also the oil tank on the engine tender must be provided with a heater coil to which in cold weather steam can be admitted from the boiler so as to reduce the oil to a proper consistency. This heater coil is illustrated by Fig. No. 7.

THE PIPING AND APPLIANCES ON TENDER AND ENGINE.

The oil tanks in the engine tender are fitted with automatic safety valves with a small chain or rope connection to the back of the engine cab

FIG. 7.

HEATER COIL—SANTA FE.

with a spring key which passes through the upright rod of the safety valve so that in case the engine breaks apart from the tender the rope or chain will pull the spring key out of the rod when the safety valve will close automatically and stop the flow of oil from the tank.

The following illustrations, Figures 8, 9, 10 and 11 indicate the details of the piping on the tender, the safety valve, the delivery pipe and fittings and the hose and fittings as used on the Santa Fe system.

In localities where heavy oil is used it is necessary to carry about five pounds pressure in the tender oil tanks to facilitate the proper flow of the oil. With light gravity oil, however, and in warm weather such pressure is not necessary. The illustration, Fig. 12, shows very clearly the general arrangement of an oil burning locomotive.

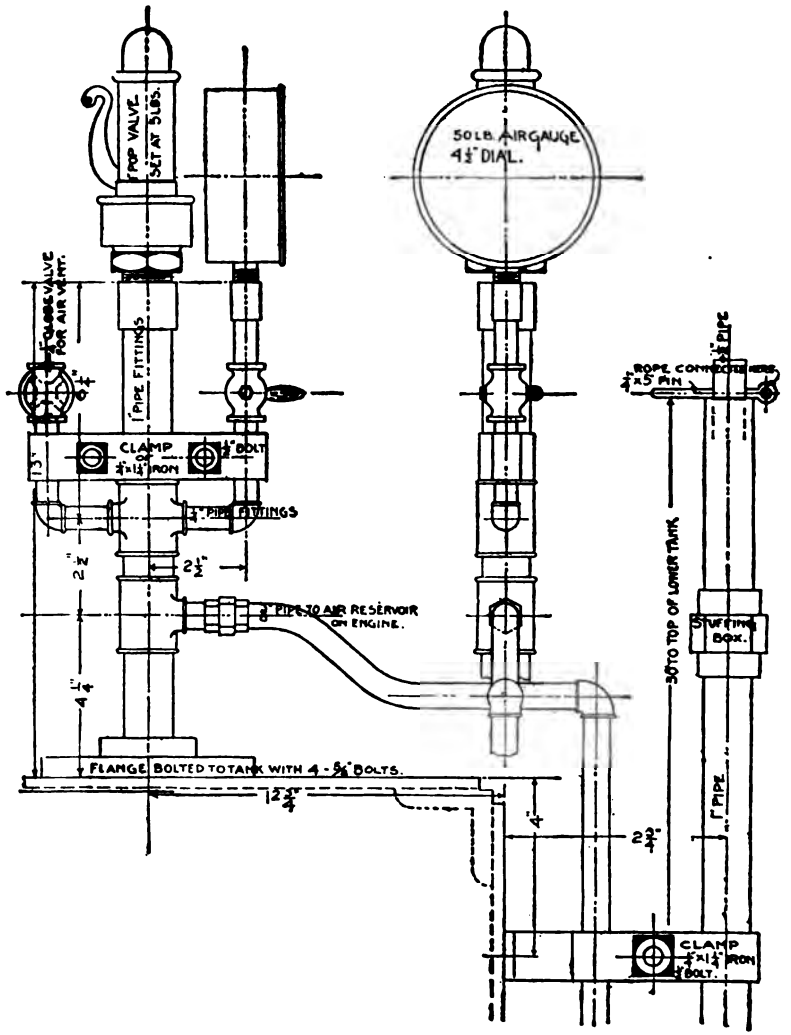


FIG. 8.

DETAILS OF PIPING ON TENDER—SANTA FE.

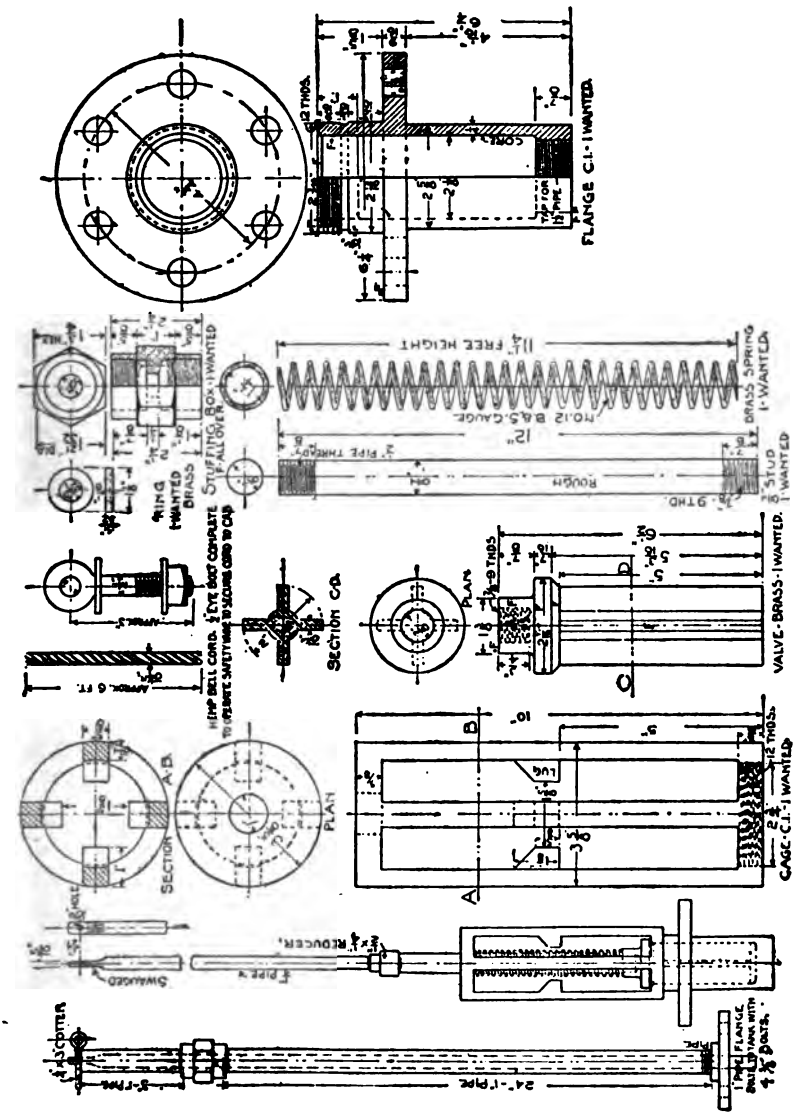


FIG. 9.

DETAILS OF SAFETY VALVE—SANTA FE.

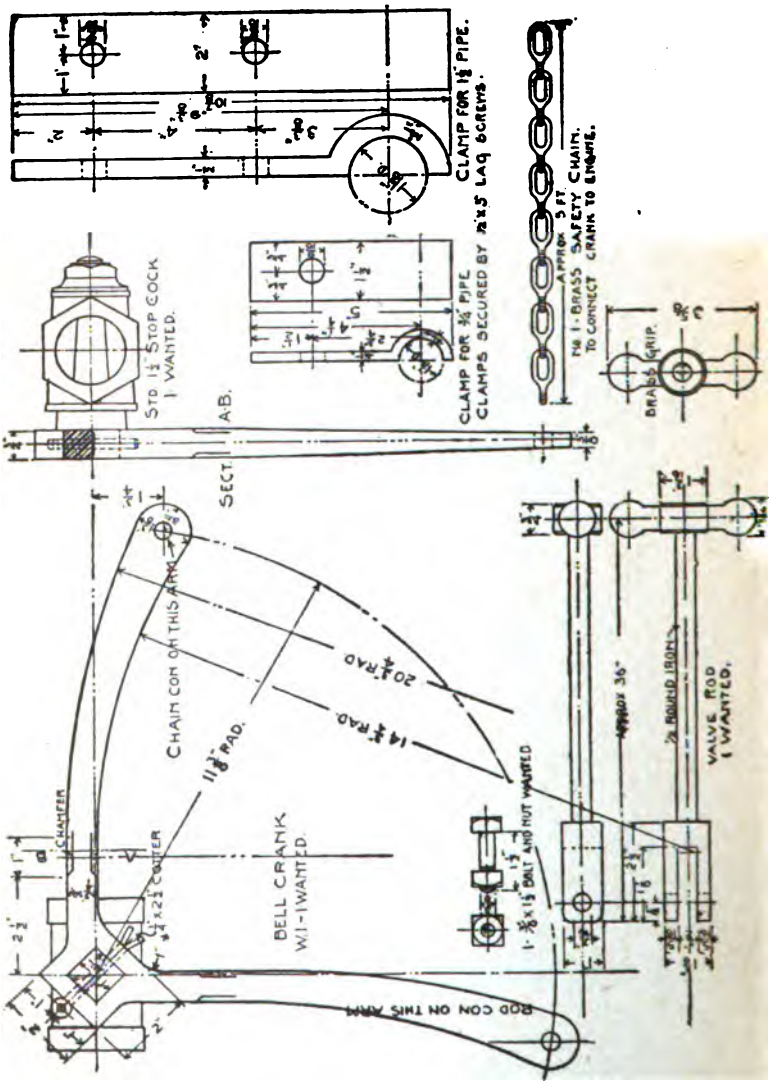


FIG. 10.

DETAILS OF OIL DELIVERY PIPE AND SPECIAL FITTINGS—SANTA FE.

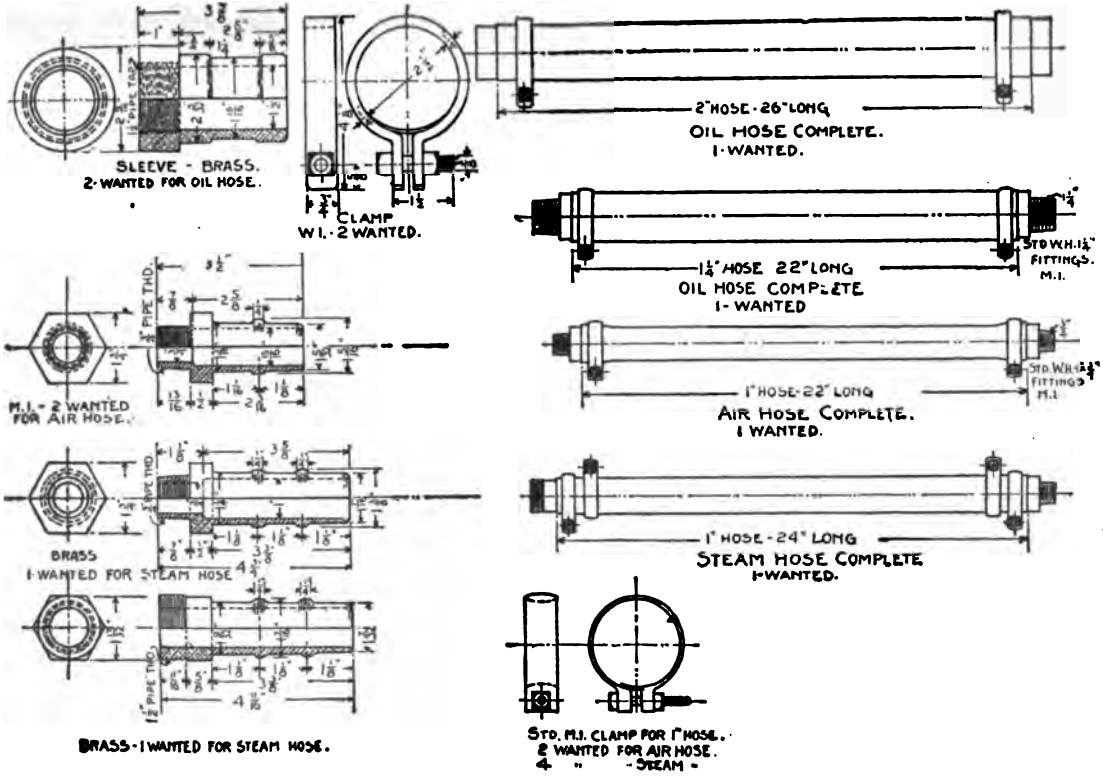

SLEEVE - BRASS.
2 WANTED FOR OIL HOSE.
CLAMP
W.I. - 2 WANTED.
2" HOSE - 26" LONG
OIL HOSE COMPLETE.
1 WANTED.
1¼" HOSE 22" LONG
OIL HOSE COMPLETE
1 - WANTED
STD W.H. 1¼" FITTINGS. M.I.
M.I. - 2 WANTED FOR AIR HOSE.
1" HOSE - 22" LONG
AIR HOSE COMPLETE.
1 WANTED.
STD. W.H. 1" FITTINGS M.I.
BRASS
1 WANTED FOR STEAM HOSE
1" HOSE - 24" LONG
STEAM HOSE COMPLETE
1 WANTED.
BRASS - 1 WANTED FOR STEAM HOSE.
STD. M.I. CLAMP FOR 1" HOSE.
2 WANTED FOR AIR HOSE.
4 " - STEAM -

FIG. 11.

DETAILS OF HOSE AND FITTINGS—SANTA FE.

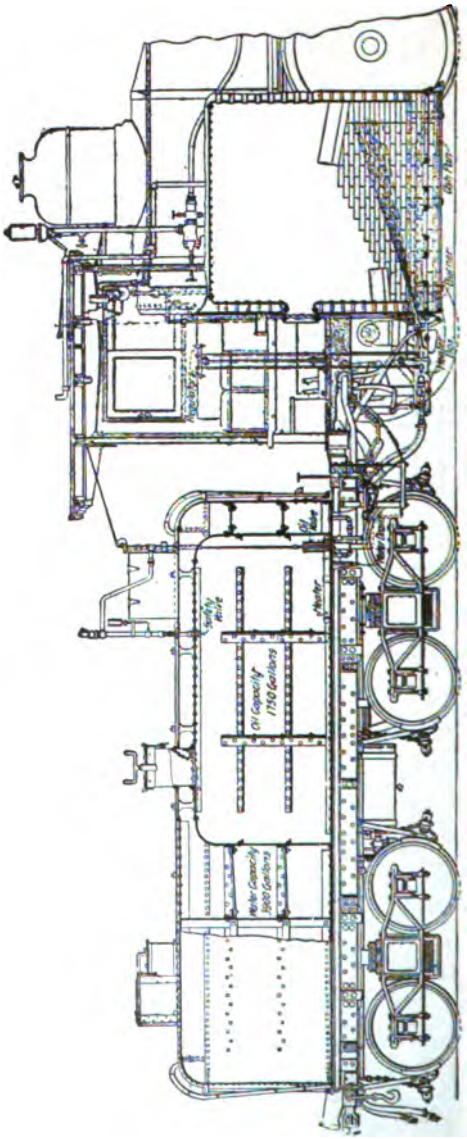


FIG. 12.

GENERAL ARRANGEMENT OF OIL BURNING LOCOMOTIVE—SANTA FE.

THE LOCOMOTIVE. CONVERTING A COAL BURNER TO AN OIL BURNER. PIPING AND BRICK WORK IN LOCOMOTIVE.

The locomotive shown in Fig. 12 is one converted from a coal burner to oil and shows the position of the different parts of the oil apparatus. In converting a coal burning engine to an oil burner it is necessary first to remove the grates and grate frame and remodel the ash pan by applying a suitable casting fitting the inside of the pan and riveted on the sides and near the top of the pan; this casting acts as a support for the brick work on the sides of the fire box and is cored out to admit the proper amount of air necessary for combustion to the fire box. The brick arch should be built as low as possible, the main purpose of which is to protect the crown sheet, crown bolts and seams from overheating. The oil burner should be secured to the bottom of the mud ring exactly central and should be placed at such an angle that the jet or spray of oil will strike just below or under the arch. Details of the arrangements of piping and brick-work of an oil burning locomotive are given in the accompanying illustration, (Fig. 14.)

The details of the fire brick used in the construction of an oil burning locomotive are shown in the drawing, Figure 15.

For the side walls and inverted arch ordinary commercial fire brick is used. Experience has shown that fire bricks which soften under heat are preferable as they form a bond which adds

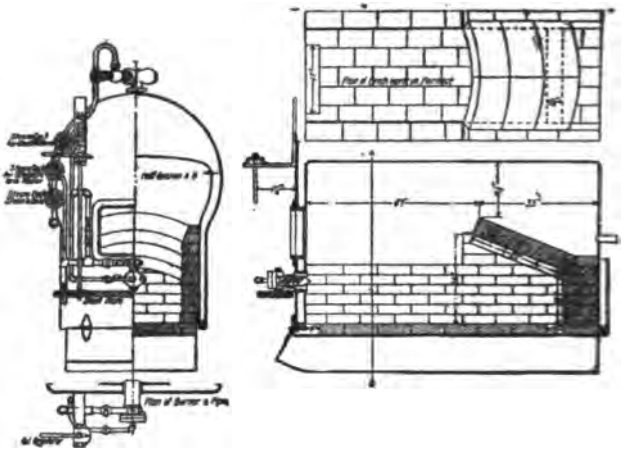


FIG. 14.

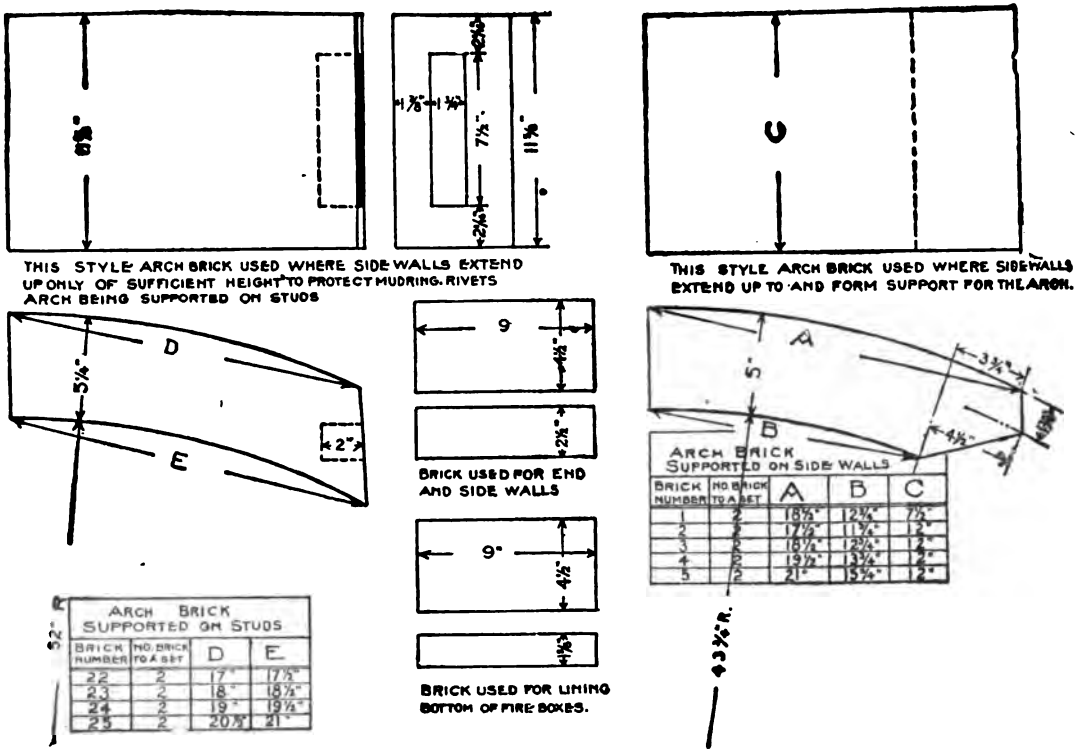
FIREBOX EQUIPMENT—SOUTHERN PACIFIC.

strength to the wall and prevents it shattering under the shocks incident to the service. Fire bricks which have very high heat-resisting qualities and which tend to crock when cooling are said to be of little use.

THE BURNER OR ATOMIZER.

One of the principal devices essential to the oil burning locomotive is, of course, the burner or atomizer, of which several designs are illustrated in the following drawings. (Figs. 16, 17, 18 and 19).

The function of the burner or atomizer is to break up the oil into a very fine spray. It is made of brass. In the Santa Fe burner, steam



ARCH BRICK SUPPORTED ON STUDS

BRICK NUMBER	NO. BRICK TO A SET	D	E
22	2	17"	17½"
23	2	18"	18½"
24	2	19"	19½"
25	2	20⅞"	21"

ARCH BRICK SUPPORTED ON SIDE WALLS

BRICK NUMBER	NO. BRICK TO A SET	A	B	C
1	2	18½"	12¾"	7½"
2	2	17½"	11¾"	2"
3	2	16½"	2¾"	2"
4	2	19½"	3¾"	2"
5	2	21"	5¾"	2"

FIG. 15.

DETAILS OF FIRE BRICK—SANTA FE.

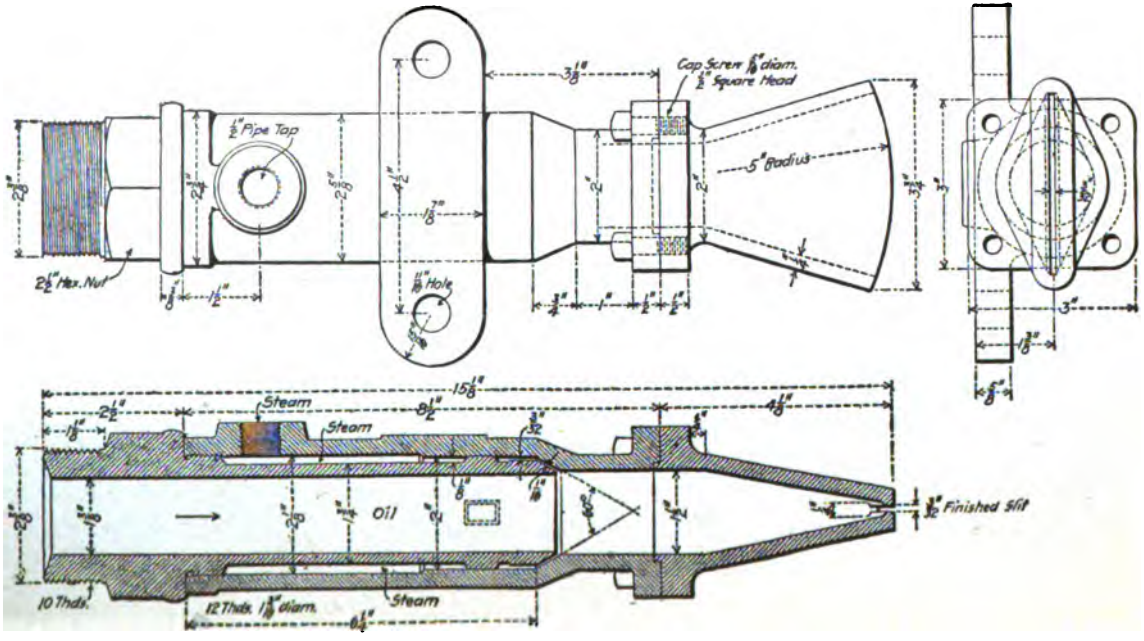


FIG. 16.

DETAILS OF "LUNDHOLM" FUEL OIL BURNER.

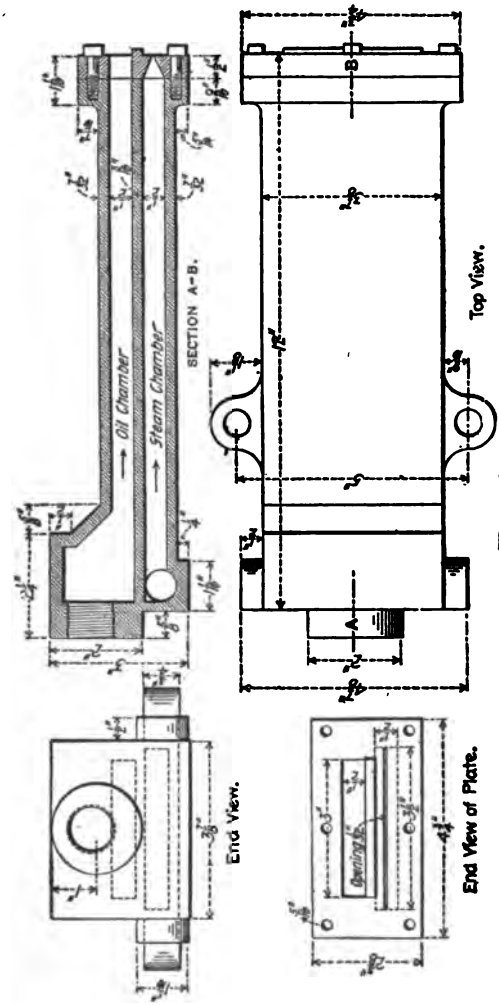


FIG. 17.

DETAILS OF "BOOTH" FUEL OIL BURNER.

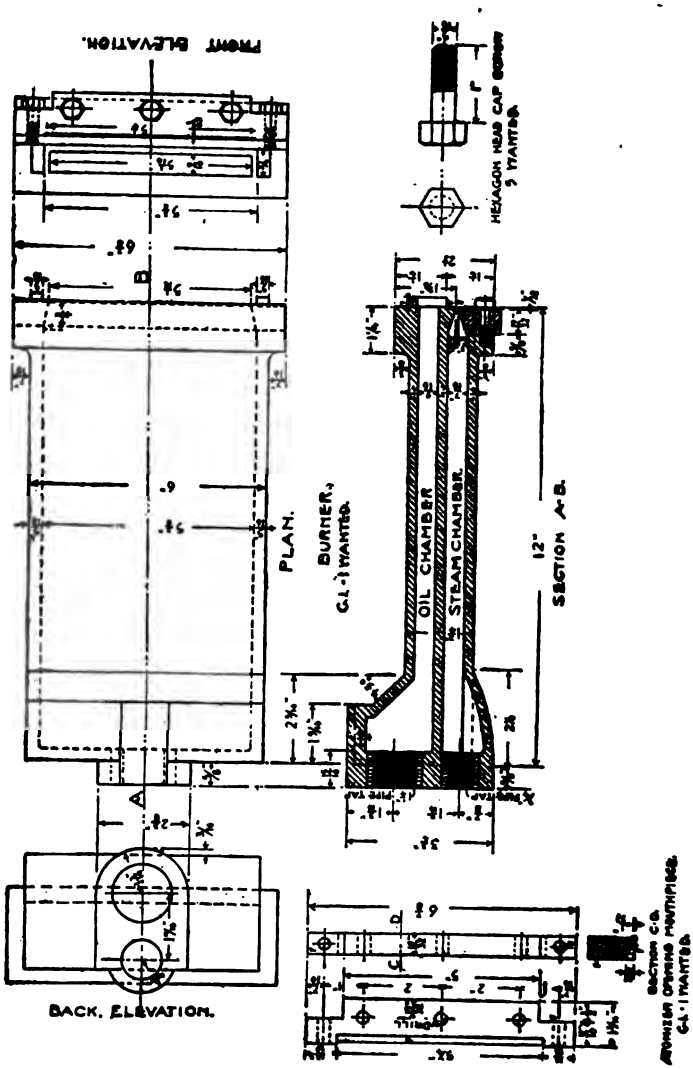


FIG. 18.

DETAILS OF OIL BURNER—SANTA FE.

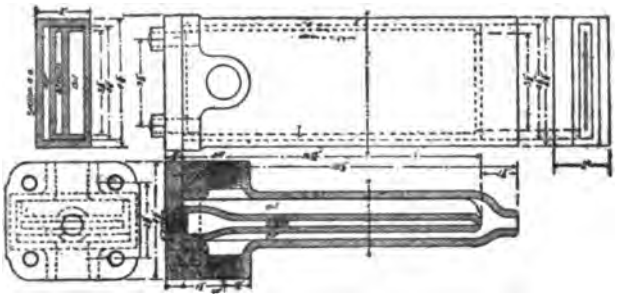


FIG. 19.

DETAILS OF OIL BURNER—SOUTHERN PACIFIC.

enters the bottom part at one end and issues through a slit at the other end. The oil flows through the upper part of the burner over the hot partition and on issuing is caught by the steam and sprayed into the fire, which, when the engine is working, is a mass of flame filling the fire box. The supply of steam and oil to the burner is regulated by the fireman from the cab, the handles of the steam and oil supply valves being located so that he can readily manipulate them from his seat.

The Santa Fe burner is rigidly attached to the mud ring; it is a casting having an oblong passage. One end of the casting is enlarged to receive connection with oil and steam pipes one above the other. The mouth of the steam passage is directly underneath the mouth of the oil passage and the effect of the steam pressure is to spray the oil as it flows from the upper passage.

In the Southern Pacific burner there are three passages: one for oil, one for steam, one for air. The oil enters the rear of the burner from above, air is conveyed from below through a narrower passage to a common mouth just behind which terminates a central tube supplying steam. The mixture of oil, air and steam is there sprayed into the fire box through one nozzle. In the Southern Pacific arrangement the burner is located near the upper part of the bricked portion of the fire box probably for the reason that the form of nozzle causes the spray to be thrown down as well as up.*

THE HEATER BOX.

In order to provide against the effect of cold weather, or where the oil is heavy or lacking in fluidity, a heater box is placed between the burner and the oil tank the purpose of which is to raise the temperature of the oil to as high a temperature as possible before it goes into the burner. The construction of this box is shown in the following illustration, (Fig. 20).

---

*The methods adopted for using oil for fuel have advanced step by step as is the case with all mechanical devices. First came the *Hearth furnace* in which the liquid is thinly distributed in pans or other receptacles and burned; then the *Gas furnace* in which the oil is transformed into gas before combustion, and, finally, the *Atomizer* by which the oil is divided into atoms so that it can be nearly completely consumed in a vaporous condition. The atomizer is the device adopted and used on American locomotives. It is certain however that the final stage has not been reached in the development of mechanical appliances for the combustion of oil.

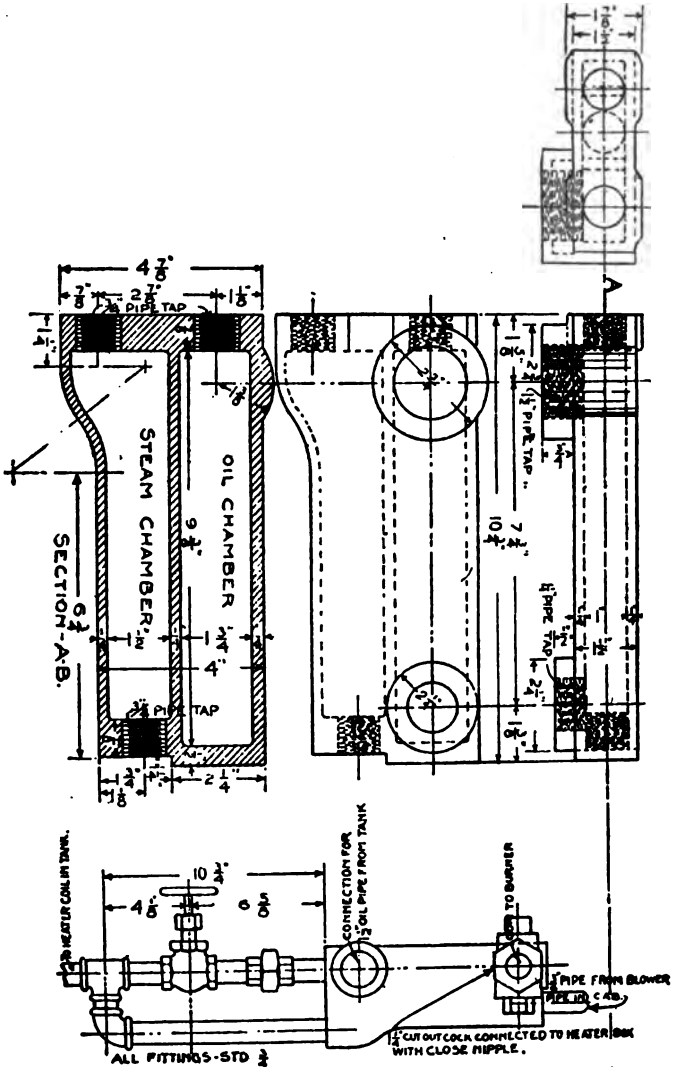


FIG. 20.

DETAILS OF OIL HEATER BOX—SANTA FE.

CAB APPLIANCES.

Detail drawings of the three way cock blower pipe connection to smoke arch and of the oil throttle valve handle are shown in the following drawings, (Figs. 21 and 22).

CLEANING FLUES. SAND FUNNEL.

In the operation of the oil burning locomotive it becomes necessary occasionally to remove the gum and soot generated in the combustion of the oil from the boiler flues. To effect this a funnel is used which is inserted in the fire door through which sand is blown by steam with force, the sand thus blown through the flues carrying with it the accretions of soot. A detail drawing of this funnel is shown in Fig. 23.

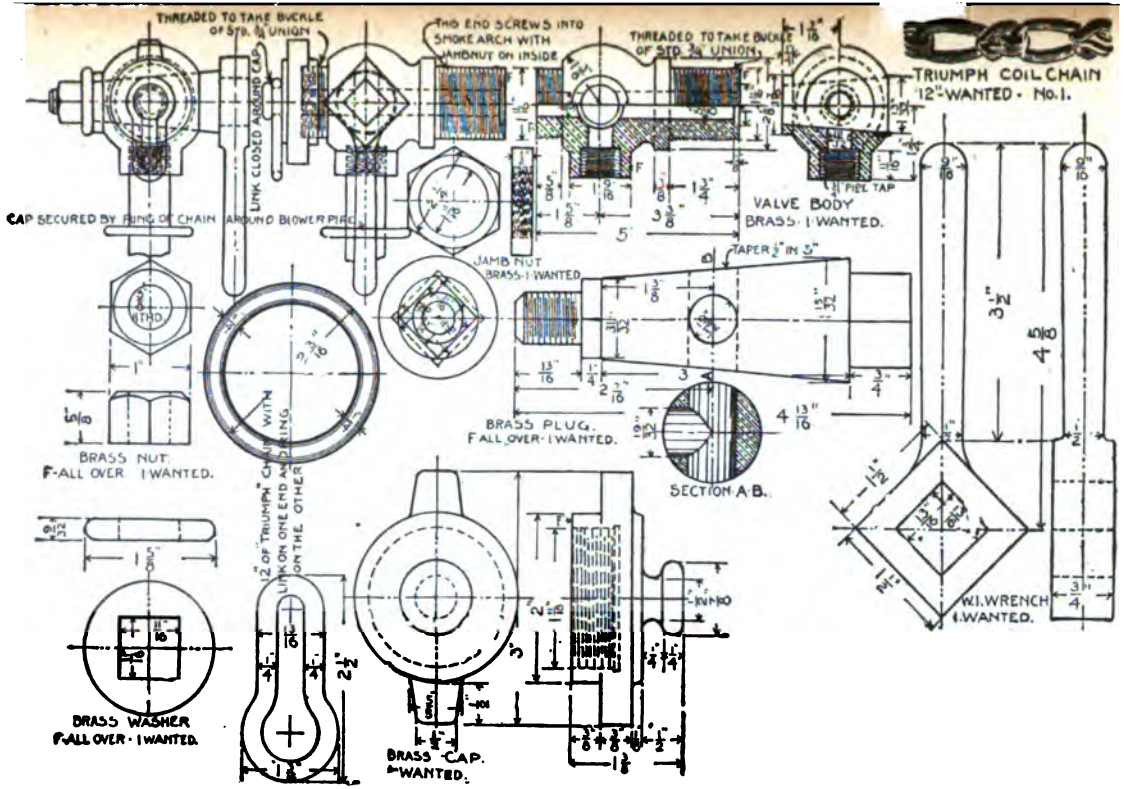

THREADED TO TAKE BUCKLE OF STD. ¾ UNION
THD END SCREWS INTO SMOKE ARCH WITH JAMNUT ON INSIDE
THREADED TO TAKE BUCKLE OF STD ¾ UNION
TRIUMPH COIL CHAIN 12" WANTED · No.1.
CAP SECURED BY RING OF CHAIN AROUND BLOWER PIPE
LINK CLOSED AROUND CAP
VALVE BODY BRASS · 1 WANTED.
¼ PIPE TAP
JAMB NUT BRASS · 1 WANTED
TAPER ½" IN 5"
BRASS NUT F-ALL OVER 1 WANTED.
BRASS PLUG. F ALL OVER · 1 WANTED.
SECTION A·B.
W.I. WRENCH 1 WANTED.
BRASS WASHER F-ALL OVER · 1 WANTED.
½" OF TRIUMPH CHAIN WITH LINK ON ONE END AND RING ON THE OTHER
BRASS CAP. 1 WANTED.

FIG. 21.

DETAILS OF THREE-WAY COCK—SANTA FE.

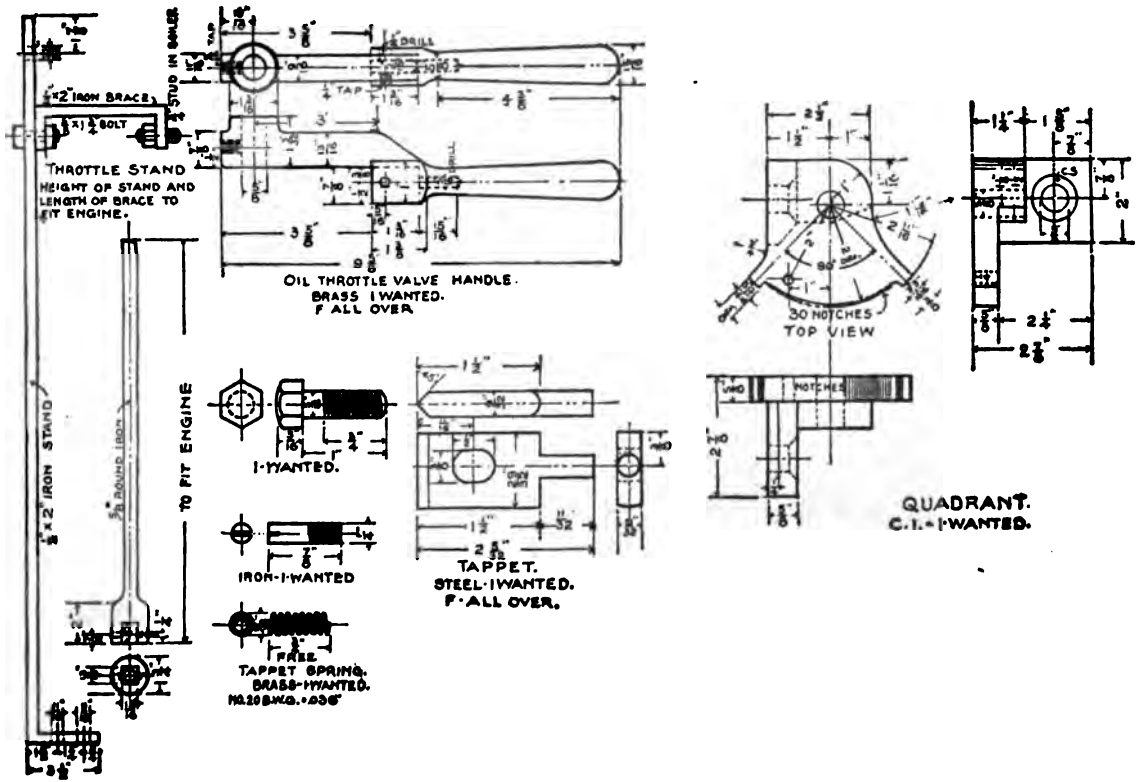
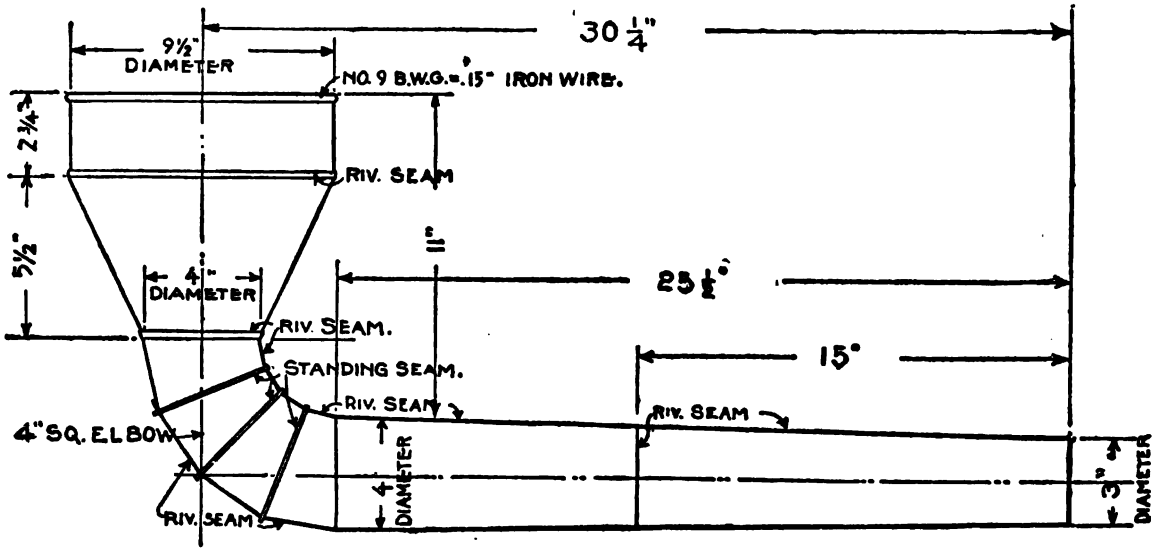


FIG. 22.

DETAILS OF OIL THROTTLE VALVE HANDLE—SANTA FE



MATERIAL NO. 26 GALV. IRON.
ONE POUND RIVETS.

FIG. 23.

SAND FUNNEL USED IN CLEANING FLUES—SANTA FE.

SPECIFIC RULES TO BE OBSERVED IN FIRING AND OPERATING.

In the operation of oil burning locomotives the following practical rules and regulations have been adopted:

In firing up an oil burning locomotive in the round house steam connection is made to the three way cock on the smoke arch which acts as a blower and atomizer at the same time; then throw in the fire box, in front of the burner, a piece of greasy lighted waist; then start the oil to running slightly; then open the atomizer valve enough to atomize the oil which is flowing from the burner, and the oil will instantly ignite. The fire should be watched until steam begins to generate in the engine, when the round house steam can be cut off. Care should be taken not to turn on too much oil, for the explosion would drive the flame out of the fire box and might be the cause of injury to the operator. Care must also be taken to see that the fire does not go out when first started in a cold engine; if it does and is not noticed the oil will run into the pit and may take fire later on and explode and thus damage the engine. The fire must therefore be carefully watched until its burning is well assured after which there is little danger of this happening. Fire going out on an oil burning engine can be detected readily by observing the smoke coming out of the stack. If it is of a white, milky color, it indicates that the fire has gone out and that the oil is still running out into the

pan; this smoke is caused by the heat of the brick in the bottom of the pan. That the fire has gone out can also be detected by the odor.

In firing up an oil burning locomotive where steam is not available, wood may be used until ten or fifteen pounds of steam is generated in the boiler. The wood must be placed in the fire box with great care so as not to damage the brick work, and in using wood for this purpose care must be taken to avoid causing fires along the right of way or elsewhere.

It is very important that the proper amount of steam be admitted to the burner as an atomizer. It is also very important that the brick walls and arch of the locomotive be kept in perfect condition. Occasionally small pieces of brick will fall down and lodge in front of the burner, which will interfere with the engine steaming. All engines should be equipped with a pair of light tongs or a hook so that the fireman can remove these pieces of brick if necessary.

In oil burning engines it is necessary to occasionally use sand for cleaning the gum off the end of flues in the fire box. This sand is applied through an elbow-shaped funnel made for the purpose; the nozzle of the funnel is inserted through an aperture in the firedoor, and when sand is being applied by the fireman the engineer drops the lever in the corner notch and has his throttle wide open. This is very effective, and is only used three or four times in going over a long hard division.

In handling the oil burner on the road the engineers and firemen must work in harmony,

i. e., when an engineer wishes to shut off the throttle he should notify the fireman in time so that the latter can close the oil valve in order to prevent waste of oil, the emission of black smoke and the "popping off" of the engine; and again, in starting up, the engineer should notify the fireman so that the oil valve may be opened before the throttle, and the fire burning before any cold air is drawn into the fire box by the exhaust. In opening the valve the flow of oil should be gradually increased as the engineer increases the working of the engine. If this rule is carried out it will in a great measure prevent leaky flues, crown and stay bolts. Fire boxes can be easily damaged by over-firing.

In a coal burner if an engine drops back five or ten pounds pressure it takes some little time to regain it; in an oil burner the fire can be crowded so as to bring it up almost instantly and thereby overheat the plates and cause damage to the fire box. The practice should be to consume about as much time in bringing up steam on an oil burner as would be taken with a coal burner; too much care cannot be exercised in this particular. It is possible to melt the rivets off the inside of an oil burner fire box by over-firing.

In drifting down long grades, it is preferable to keep the fire burning a little rather than to shut it off entirely to prevent chilling of the fire box, adjusting the dampers to suit a light fire. The water can be carried in such a way approaching such points as will admit of working the injector occasionally to prevent popping off.

The use of the blower should be restricted all possible. It tends to make the fire box leak. If the blower is used at all it should be used very lightly, simply enough to cause a draught.

Some troubles have been encountered on account of waste getting into the oil tank; these are caused by carelessness on the part of Hostlers and Helpers in measuring the oil and wiping the measuring stick off with waste. Waste should therefore not be used for this purpose.

Do not approach the man hole or vent holes of a tank closer than ten feet with a lighted torch or lantern.

Do not take a lighted torch or lantern to a man hole to ascertain the amount of oil in the tank; this should be done by the insertion of a stick or rod and the same carried to the light to ascertain the number of inches of oil shown on the stick or rod.

Do not, when making repairs to, or inspection of, an empty tank, place a lighted lamp or torch inside of the same before it has been thoroughly steamed and washed out, as gas will accumulate in an empty tank not so steamed and washed out, and explosion is liable. Employes are positively prohibited from entering tanks having contained crude oil, until the instructions to thoroughly steam and wash them out have been complied with.

Do not, in firing up, apply the atomizer and oil before putting in the lighted waste, as gas may accumulate in the fire box and thus cause an explosion.

In starting up or stopping, the engineer must always notify the fireman, as the starting or shutting off of fire must in all cases precede the opening and shutting off of the engine.

Do not force the firing. Bring the fire box temperature up gradually. If pressure falls back five or ten pounds, restore the maximum pressure by gradual degrees. Forced firing will overheat the plates, burn off rivet heads, and cause leaks.

In sanding the flues to clean out the accumulations of soot and gum, drop the lever to half stroke and use full throttle for a few turns, while the sand is being injected.

Successful combustion of petroleum is smokeless.

An accurate combination of steam and oil in the atomizer and air admission is necessary to thorough combustion. To this end the steam and oil valves and dampers must be adjusted closely.

As all petroleum contains a greater or less per cent of volatile gases, which are given off at low temperatures, lighted torches, lamps or lanterns should never be taken in or near tanks containing oil.*

The following rules are enforced by another Company,† viz:

Before departure, see that the oil tanks are full, the oil heater in operation and the oil heated to a proper temperature as soon as possible; also

* The foregoing rules are those in force on the Santa Fe system.

† The Southern Pacific. Further and more detailed rules of the Southern Pacific Company, together with drawings showing details adopted by that Company, are given at the close of this chapter.

that the fire is burning, that no oil is dropping or lying in the outer pan, that no brick or other obstruction to the free passage of oil from the burner to the front wall is lying on the bottom of the inner pan, and that the sand buckets are full.

Starting the Fire.—When the firebox is below igniting point, which is a dull red, open the dampers, start the blower and atomizer medium hard, throw a piece of saturated oily waste, after lighting same, on to the bottom of the inner pan, close and fasten the firebox door, then turn on the oil very light, and see if it ignites at once. If not, shut off the oil at once, and see if the waste is burning. When the oil has ignited, reduce the blower and atomizer to very light feed; also reduce the oil flow until the stack becomes almost clear. In starting the fire by the hot firebox, no waste is used.

Temperature of Oil.—Kern River or thick oil should be heated to from 150 to 170 degrees, McKittrick or thin oil to from 100 to 120 degrees; the temperature should be taken from the measuring rod suspended in the forward tank. Vents on the top of the oil tanks should be kept open at all times, except when tanks are very full and oil is liable to splash out, when they may be kept closed until the oil is reduced from 5 to 7 inches in the tanks, care being taken not to have any lights in the hands when they are first opened after having been closed any length of time.

Heating Oil by Direct Steam Application.—Put the heater on strong until the oil has reached

the proper temperature, then close it off and give it another application. To keep the heater on light and constant might produce water enough in the oil to become objectionable.

Heating by the Coil in Tank.—Open cock on boiler head just sufficient to produce steam water at drain cock under tank. Superheater should be used constantly when weather is anyway chilly. Keep drain cock to superheater open just sufficient to keep cylinder dry.

Starting Train or Engine.—The engine should not be started until the fireman is at the firing valve. Remember that the care of the fire box is as important as keeping up steam or making time. Start the engine carefully, so, if possible, not to slip engine. Open the firing valve sufficiently to make sure that the action of the exhaust will not put out the fire, but not enough to make a great volume of black smoke. Increase the atomizer and oil gradually until full speed is attained, keeping just on the verge of black smoke. When the engine is hooked up, the valves governing the admission of oil should be regulated according to amount required. It is well to use the blower about one-half turn while starting, as this will help to consume the smoke between exhausts and keep the engine hot.

Black Smoke.—Never make an excessively heavy smoke, as it only fills the flues with soot. Soot is a great non-conductor of heat and produces no heat in itself, therefore strive to keep the stack clear at all times except when starting.

Sanding Flues.—Sand as frequently as required, according to the amount of smoke made.

If the engine has to be smoked anyway hard, sand every 10 or 12 miles, but if the stack is kept clear, sand only every 30 to 50 miles. If any amount of switching is done at a station, sand immediately after leaving that station. How to sand: Having attained a fair rate of speed use about one quart of sand, close all the dampers, put the reverse lever near full stroke, open the throttle wide and allow the sand to be drawn from the funnel in a thin stream. Going into a station where stops are to be made great care should be exercised not to cut the oil supply too low before the throttle is closed.

Any draft through the fire box has a tendency to put the fire out; the stronger the draft the stronger must be the oil supply. Consequently there is great danger of the fire being put entirely out before the throttle is closed. When the throttle is closed and oil reduced, the atomizer should be cut down at once, so that it will just keep the oil from dropping onto the bottom of the inner pan, otherwise the intense heat of the fire box will be blown down through the air inlet burning the bottoms of the pans.

Never allow the fire to be put entirely out, except when giving up the engine at the end of a run or when all hands are going away from the engine. Then it must be put out. To put out fire: First close the stop-cock under the tank, allow the oil to all be drawn from the pipe and burner, then close the firing valve, atomizer and all dampers. To blow obstruction from oil line: Close the firing valve, open the cock between

the heater line and the oil line, close the heater line and turn the cock on boiler head to the heater line on full. This will blow all obstructions back into the tank. This arrangement may be used to heat the oil in the tank in case of failure of the coil heater. If any brick from the walls or arches in the fire box should fall in front of the burner, it must be removed at once or pushed to the extreme front of the fire box. Blue gas issuing from the stack is an indication that the fire is out or very nearly so; it is very objectionable and should be avoided if possible, especially on passenger trains.

Burners must be adjusted so that the oil will strike about the middle of the front wall. If the oil drops on the bottom of pan, black smoke and poor steam will be the result. Burners are liable to clog up with sand that is in the oil and by pieces of waste that are sucked up through the air inlet. If trouble is found with it, the inner case or steam jet can be taken out in most cases without disturbing the outer case or the adjustment of the burner. In this manner any obstruction or defect may be readily located and remedied. The blower should never be used stronger than just sufficient to clear the stack of black smoke. Any more is only a waste of fuel and a delay, as too strong a draft through a fire box for the amount of oil admitted only absorbs heat and cools instead of heating the fire box. At water tanks, where it is necessary to keep the injector on all the time the train is standing, the oil supply should be left on a little heavy and the

blower on lightly. This will insure a full head of steam when ready to start. As the oil penetrates the arch brick and causes them to crumble away very fast, it is important to examine the fire box frequently to know its condition. As steam pressure increases on the boiler, the atomizer and blower will work stronger unless they are cut down. Be governed accordingly. Also remember that black smoke is very detrimental to steam generating and that the more that is made, the more it becomes necessary to make.

THE BALDWIN OIL BURNING LOCOMOTIVES.

The following is a description of the devices used by the Baldwin Locomotive Works, many of whose oil burning locomotives are in use both in the United States and Russia.

The burner, shown in figure 24, is rectangular in cross-section, with two separated ports or chambers, (one above the other), running its

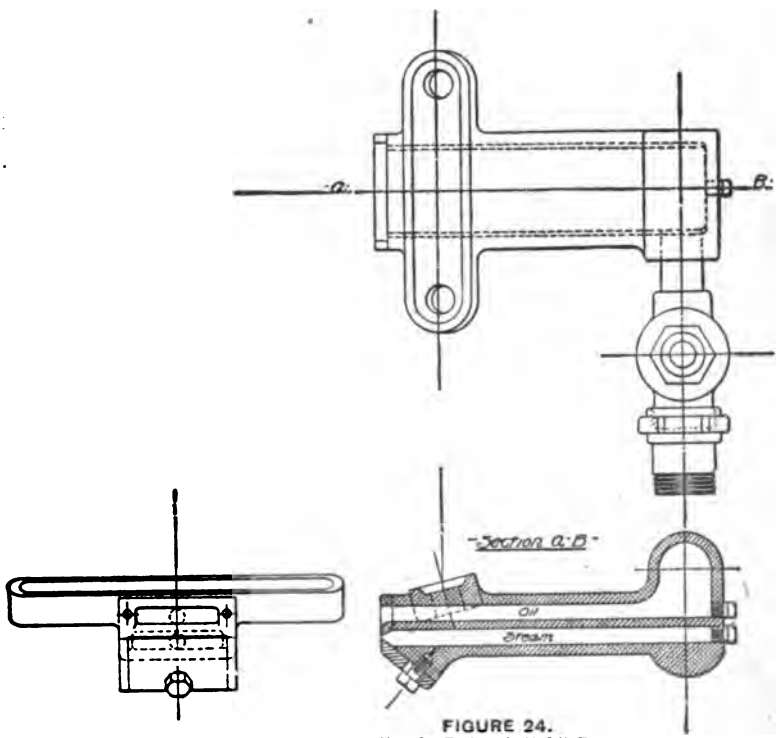


FIGURE 24.
Details of "Baldwin" Oil Burner.

entire length. Into the upper of these ports the oil from the reservoir is admitted through suitable pipes. The flow of oil is controlled by a plug cock in the feed pipe, provided with an operating handle placed in the cab within easy reach of the fireman. Steam is admitted to the lower port of the burner through a pipe connected to the boiler in such a manner as at all times to insure the introduction of dry steam. The valve controlling the admission of steam is also conveniently located in the cab close to the fireman's seat. A free outlet is allowed for the oil at the nose of the burner; the steam outlet, however, is contracted at this point by an adjustable plate which partially closes the port, and gives a thin, wide aperture for the exit of the steam. This arrangement tends to wire-draw the steam and increase its velocity at the point of contact with the oil, giving a better atomizing effect. A permanent adjustment of the plate can be made for each burner after the requirements of service are ascertained. The moving of the plate would not then be required except for cleaning purposes. The oil, as it passes through the burner, is heated to a certain extent by the effect of the steam in the lower portion, and flows freely in a thin layer over the orifice. It is here caught by the jet of steam issuing from the lower port, and is completely broken up and atomized at the point of igniting. The oil is carried into the fire box in the form of vapor, where it is mingled with a sufficient quantity of oxygen from the incoming air to insure as near as possible perfect

combustion. For the size of the burner it is computed that one inch in width is suitable for one hundred inches of cylinder area. The proper width of burner for any locomotive may therefore be obtained by the following formula:

$$\frac{B=C^2 \times .7854, \text{ in which}}{100}$$

B=width of burner in inches.
C=diameter of cylinder in inches.

The oil pipe leading to the burner should be made of ample size to insure a full supply, as it is essential that a regular flow be maintained; a small pipe would be found inadequate with oil having a sluggish tendency. Any interference with the flow, other than that interposed by the feed cock, causes a loss of efficiency.

At times, especially when the locomotive is standing still at stations or when drifting down grade, it is desirable to allow only a small supply of oil to enter the burner. To accomplish this, the feed cock, Figure 25, is used. The passageway through the plug of this cock, which regulates the supply of oil, is made square, as shown in the cross-section. As the plug is turned

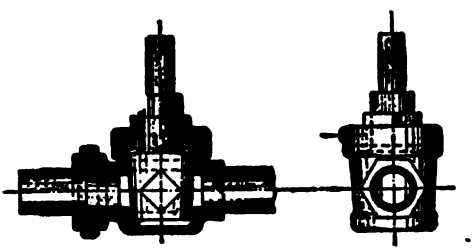


FIGURE 25.
Details of "Baldwin" Feed Cock.

to cut off the flow, the opening retains its angular form and a finer feed adjustment is attained than is possible with a cock of ordinary construction, where the hole in the plug is circular in form; it is also less liable under such circumstances to become clogged by refuse in the oil.

With a fire box such as is ordinarily used for burning coal, the changes necessary to adapt it for burning oil are easily accomplished. The general arrangement of a fire box of this description is shown in Figure 26. The burner is placed below the mud-ring at the back and on a line with the center of the boiler, and it is pointed upward at a slight angle to allow the spray to enter the fire box. A fire brick arch at the front of the fire box protects the tubes and gives direction to the heated gases, to insure their mingling with the incoming air. The throat sheet below the arch is protected with a wall of fire brick, and a layer of the same material is placed on the grate-bars (or equivalent supports), which extends back from the front wall covering about half the bottom area of the furnace. A fire brick hearth is placed under the burner to catch any oil which may drop from it. A course of brick is also placed on each side, sufficiently high to protect the side sheets of the furnace from excessive heat. A device correspondent to the ash-pan of an ordinary locomotive is fitted with a damper, preferably at the back, to govern the admission of air. This damper should be made as large as possible, with heavy frame, and arranged to close perfectly air-tight. Heavy

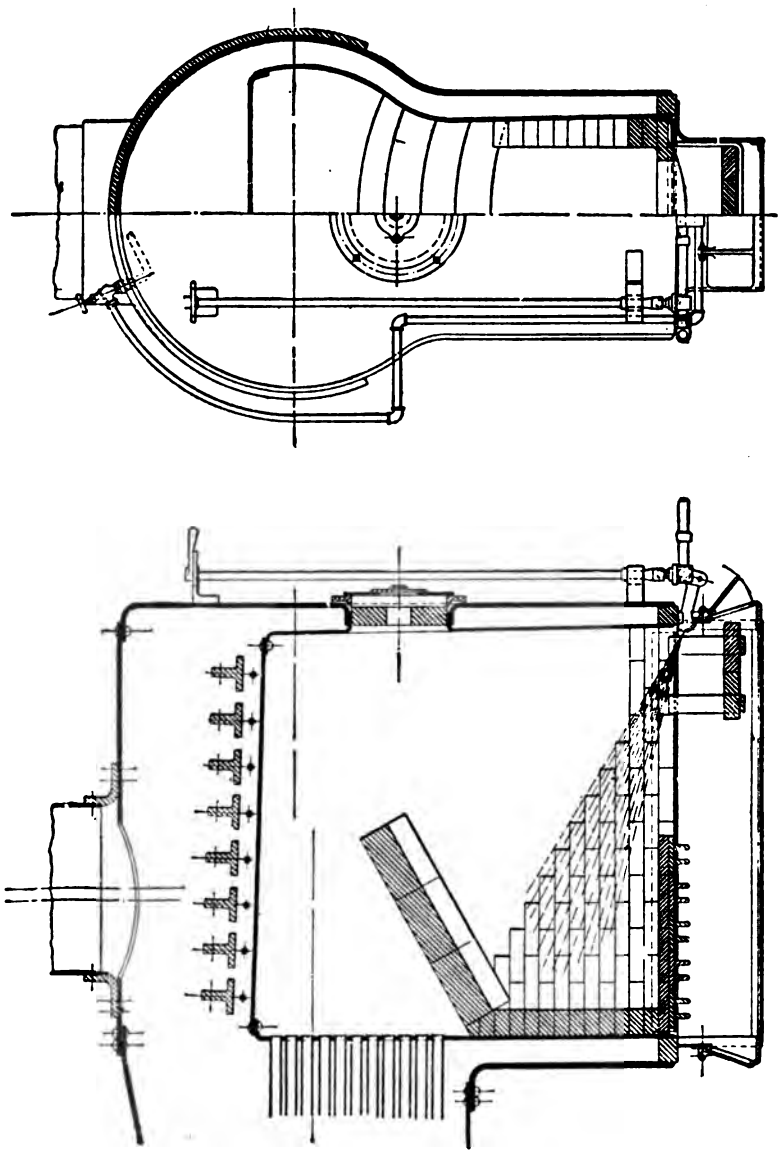


FIGURE 26.
Details of Fire-box Brick Work for Ordinary "Baldwin" Coal Burning Locomotive.

operating rods should be provided in order to withstand rough usage. The proper admission of air is an important feature, and the means for regulating it should be carefully adjusted to give a sufficient supply when needed for combustion, and on the other hand, to entirely stop the supply and avoid the loss of heat which would be occasioned by a circulation of cold air through the fire box and tubes when the oil supply is cut off. A plate with a convenient sight hole may take the place of the fire door, or the fire door may be retained, care being taken that the joints are perfectly air-tight; in either case a protection of fire brick should be provided for the inner surface to avoid the liability of warping the metal.

Boilers fitted with the Vanderbilt type of fire box have shown excellent results in burning fuel oil. This fire box, as is well known, is circular in cross-section, being rolled in the form of a large corrugated tube, and is peculiarly adapted to the class of fuel under consideration.

The arrangement of the fire brick used in the Vanderbilt type of fire box is shown in Figure 27. It is generally similar in arrangement to that already described, the only variations being those suggested by the structural changes in the boiler. The burner is introduced through the lined casing forming the back head of the boiler, and is located a short distance above the bottom of the fire box. The corrugated sheet forming the fire box is protected at the bottom and a portion of the sides by a lining of fire brick. The front wall and arch are placed at a suitable distance

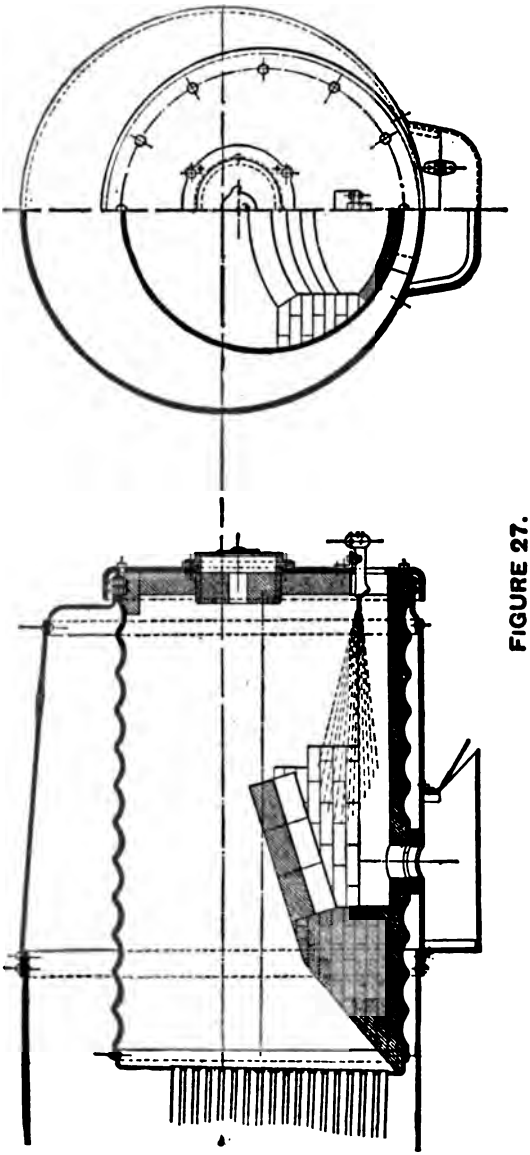


FIGURE 27.
Details of Fire-box Brick Work for "Vanderbilt" Type of Fire-box.

back of the tube sheet, to allow an unobstructed entrance to all the tubes by the heated gases, forming also a combustion chamber at the front of the furnace.

In burning oil, the combustion being more perfect than in burning coal, the heat generated in the fire box will be greater. Care should therefore be taken in setting the fire brick not to choke the passage between the upper portion of the arch and the crown sheet. If this area is insufficient, the products of combustion will impinge upon the crown sheet, and the intense heat generated at this point is liable to be detrimental to the sheet.

The forced draft occasioned by the exhaust should be so regulated as to be equally distributed through all the tubes. This can be accomplished by a careful adjustment of the "petticoat pipe" and deflecting plate. If a collection of soot appears on the sheet around some of the tubes, it will indicate that the draft through these tubes is not sufficient, and a readjustment of the draft rigging should be made until no such indications are perceptible. It is suggested that after the draft rigging in the smoke-box has been satisfactorily adjusted, it be rigidly attached to the boiler in such a manner as to be readily removed and replaced without liability of derangement.

As the weight of oil used by a locomotive for a given distance is about one-half the weight and bulk of coal for the same distance, it is obvious that a saving is made in the dead weight hauled, or with the same weight, fuel for a much longer

run may be carried. In locomotives without tenders it is often difficult to arrange for an adequate supply of coal without encroaching upon space required for other purposes. This difficulty is largely overcome when oil fuel is used, as the reservoirs can be located where it would be impracticable to place a coal bunker, and in this way room for a sufficient supply of fuel is easily obtained.

The tender tank of an oil-burning locomotive is usually constructed with two compartments, the upper being used as a reservoir for the oil and the lower for water. The partition which separates these compartments, and which forms the bottom of the oil reservoir is preferably inclined toward the front, to allow the oil to flow by gravity to the feed outlet. In cold climates a coil of steam pipe may be placed in the reservoir around this outlet, in order to rarefy the oil and insure an even and continuous flow.

ECONOMIC VALUE OF OIL AS FUEL.

"Fuel oil can be used in almost any form of firebox, the best location for the burner being just below the mud ring, spraying upward into the firebox. In some recent experiments with oil of eighty-four degrees gravity, 140 degrees flash and 190 degrees fire test, in which the boiler had twenty-seven square feet grate area and 2135 square feet of heating surface (eight per cent being in the firebox), it was found that there were about thirty-nine pounds of oil burned per square foot of grate area, and about .45 pounds per square foot of heating surface per hour, the equivalent evaporation from and at 212 degrees being about twelve and one-half pounds of water per pound of oil. It was also computed that there should be about one-third inch width of burner for each cubic foot of cylinder volume, or width of burner in inches equals:

$$\frac{\text{Volume of both cylinders in cubic feet}}{8}$$

or that one inch width of burner was sufficient for 600 square feet of heating surface.

"In the foregoing calculation, the figures are based on single expansion engines only. In compound locomotives the consumption of water will be ten per cent and the fuel about twenty per cent less than in single-expansion engines. By the above formula, in calculating the width of burner for compound engines, the volume of only the high-pressure cylinder or cylinders should be considered."*

* Report of Committee of American Railway Master Mechanics' Association, 1899.

To determine the value of oil, it is necessary to know the evaporative power of the boiler for each pound of fuel burned, which depends greatly upon the ratio of heating surface to grate surface, and the volume consumed in a given time. These conditions do not seem to affect the consumption of oil, the evaporation being about the same per pound of oil for all rates of combustion, it being impossible to consume the oil without a proper supply of air, and, as no smoke is made, no unconsumed fuel goes out of the stack, as is the case with soft coal. The following formula, based on experiments made by the Baldwin Locomotive Works, with a locomotive having compound cylinders, will give an approximate idea of the value of oil fuel as compared with coal:

$$\frac{\text{Cost of coal per ton} + \text{cost of handling (say 50 cents)} \times 10.7 \times 7}{2000 \times \text{evaporative power of coal}}$$

equals price per gallon at which oil will be the equivalent of coal.

It must be remembered in these computations that the cost of both oil and coal is considered at the place where they are delivered to the engine, and not at the place where they are purchased by the railroad company.

The following table gives the weight and volume of crude petroleum based on a specific gravity of .91, which is about the average of the Texas oil, as well as that received from South America:

WEIGHT AND VOLUME OF CRUDE PETROLEUM.

Pound.	U. S. Liquid, Gal.	Barrel.	Gross Ton.
1	.13158	.0031328	.0004464
7.6	1.	.02381	.003393
319.2	42.	1.	.1425
2240.	294.72	7.017	1.

For convenience in obtaining correct approximate weights of petroleum oil, the following gravity conversion table can be used:

Degrees Baume.	Degrees Sp. Grav.	Lbs. in 1 Gal.	Degrees Baume.	Degrees Sp. Grav.	Lbs. in 1 Gal.	Degrees Baume.	Degrees Sp. Grav.	Lbs. in 1 Gal.
10	1.0000	8.33	32	8641	7.20	54	.7608	6.34
11	.9929	8.27	33	.8588	7.15	55	.7567	6.30
12	.9859	8.21	34	.8536	7.11	56	.7526	6.27
13	.9790	8.16	35	.8484	7.07	57	.7486	6.24
14	.9722	8.10	36	.8433	7.03	58	.7446	6.20
15	.9655	8.04	37	.8383	6.98	59	.7407	6.17
16	.9589	7.99	38	.8333	6.94	60	.7368	6.14
17	.9523	7 93	39	.8284	6.90	61	.7329	6.11
18	.9459	7.88	40	.8235	6.86	62	.7290	6.07
19	.9395	7.83	41	.8187	6.82	63	.7253	6.04
20	.9333	7.78	42	.8139	6.78	64	.7216	6.01
21	.9271	7.72	43	.8092	6.74	65	.7179	5.98
22	.9210	7.67	44	.8045	6.70	66	.7142	5.95
23	.9150	7.62	45	.8000	6.66	67	.7106	5.92
24	.9090	7.57	46	.7954	6.63	68	.7070	5.89
25	.9032	7.53	47	.7909	6.59	69	.7035	5.86
26	.8974	7.48	48	.7865	6.55	70	.7000	5.83
27	.8917	7.43	49	.7821	6.52	75	.6829	5.69
28	.8860	7.38	50	.7777	6.48	80	.6666	5.55
29	.880,	7.34	51	.7734	6.44	85	.6511	5.42
30	.8750	7.29	52	.7692	6.41	90	.6363	5.30
31	.8695	7.24	53	.7650	6.37	95	.6222	5.18

TABLE SHOWING RELATIVE HEAT PRODUCING POWER OF OIL AND COAL.*

	Pounds Oil.	Pounds Coal.
Theoretical Anthracite	1	1.61
Theoretical Bituminous	1	1.37
†Urquhart's Experiments	1	1.756
Peninsular Car Co. (1885)	1	1.742
Elevated R. R. New York (1887)	1	1.785

* Prepared by Dr. Charles B. Dudley, Chemist, Pennsylvania R. R. in 1888. In this table it is assumed that:

1 lb. Anthracite Coal contains 90 per cent carbon.
1 lb. Bituminous " " 85 " "
and 5 per cent hydrogen.
1 lb. Oil contains 86 per cent carbon and 14 per cent hydrogen.

The heat-producing power of the carbon and hydrogen is calculated by means of the well known heat units of these two substances.

† Thomas Urquhart, Locomotive Superintendent, Grazi-Tsaritzin Railway, Russia, was among the first to adapt locomotives to the use of oil. The use of solid fuel on this line was entirely abandoned in 1885. He designed a burner which was one of the first to utilize a jet of steam to atomize the oil as it enters the firebox. This method has been generally adopted in the construction of the most successful burners now in use.

TABLE SHOWING RELATIVE VALUE OF OIL AND COAL, FUEL ACCOUNT ALONE CONSIDERED.*

OIL PER BARREL AT	COAL PER TON AT
$0.20	$0.74
.30	1.12
.40	1.49
.50	1.86
.60	2.24
.70	2.61
.80	2.98
.90	3.35
1.00	3.73
1.10	4.10
1.20	4.47
1.30	4.85
1.40	5.22
1.50	5.59
1.60	5.97
1.70	6.34
1.80	6.71
1.90	7.08
2.00	7.45

* Prepared by Dr. Charles B. Dudley.

TABLE SHOWING RELATIVE VALUE OF OIL AND COAL, ALL ASCERTAINED ECONOMIES CONSIDERED.*

OIL PER BARREL AT	COAL PER TON AT
$0.20	$0.65
.30	.98
.40	1.30
.50	1.63
.60	1.96
.70	2.28
.80	2.61
.90	2.93
1.00	3.26
1.10	3.59
1.20	3.91
1.30	4.24
1.40	4.56
1.50	4.89
1.60	5.22
1.70	5.54
1.80	5.87
1.90	6.19
2.00	6.52

* Prepared by Dr. Charles B. Dudley.

TABLE SHOWING ADVANTAGES CLAIMED FOR OIL OVER COAL.

Reduction of waste fuel.
Economy in handling fuel.
Less weight of fuel to haul.
Fewer repairs to locomotives.
Economy in cleaning locomotives.
Less waste of steam at safety valve.
Economy in cleaning ballast.
Economy of space required for fuel.
Elimination of fires from sparks.
Elimination of smoke and cinders, adding to comfort of passengers.
Increased utilization of heat.
Can be lighted instantly.
Requires no stoking.
Can be regulated instantly and easily.
Makes no clinkers requiring frequent removal.
Engine can be turned quicker.
Makes no refuse or cinders to be handled.
Insures freer steaming and running, affording greater ability to handle maximum loads.

DETAILED RULES ADOPTED BY THE SOUTHERN PACIFIC COMPANY, GOVERNING THE HANDLING OF OIL BURNING LOCOMOTIVES.

1. WATER IN PAN.—All engines are provided with a sprinkler pipe to ash pan, which should in all cases be opened to carry off any oil drippings that reach the pan when starting the fire. This prevents combustion in the pan when the oil becomes heated. In case of crews or watchmen having to leave their engine for a short time, this precaution should also be taken.

2. STARTING FIRE.—Before starting fire, see that the bottom of the firebox, in front of the burner, is free from brick or any obstruction that would interfere with the free passage of oil from burner to front of firebox. Open blower strong enough to create necessary draft. Open atomizer valve long enough to blow water out of pipe; then close valve and light a piece of oily waste and throw it to center of firebox; then turn on atomizer strong enough to carry oil to fire. Open oil valve slowly until the oil ignites, using only enough oil to generate steam without making black smoke.

In firing up a cold engine the fire may go out; watch it closely until the engine is hot.

If at any time it should become necessary to fire up with wood, care should be taken that the brick work is not damaged.

3. PUTTING OUT FIRE.—First shut off the oil valve on tank; allow oil to be burned from pipe to burner, then close firing valve, atomizer and dampers. It is important that dampers should be closed to prevent passage of cold air through firebox and tubes when they are heated, after fire has been extinguished.

4. DRUMMING OF ENGINE.—Drumming of engines is caused by faulty construction of brick work in firebox; careless handling of oil valve by fireman when engine is working slowly, or by atomizer valve being opened too much.

Firemen on suburban trains should use the utmost care in handling oil valves and atomizers, with the view of avoiding disturbances of this character.

5. TEMPERATURE OF OIL.—To obtain the most economical results, the temperature of the oil in the tank should not exceed 100 degrees, as it is again heated in the super-heater. When oil in tender storage tanks is heated by direct steam, it is important that no more steam be admitted than absolutely necessary, as the condensation is liable to prevent continuous flow of oil to burner.

6. BLACK SMOKE.—Black smoke should at all times be avoided, and if in evidence, shows faulty construction of brick work or improper methods of handling. The soot formed by smoke is a non-conductor and will make an oil-burning engine fail in steam quicker than any other cause. An accurate combination of oil and steam in the atomizer, with the proper admission of air, is necessary to thorough combustion. To prevent smoke in starting and stopping, engineers should always notify the firemen when they are going to open or close a throttle.

CAUSES OF FAILURES AND HOW TO PREVENT THEM.

1. SMOKE WHICH STOPS UP THE FLUES WITH SOOT.—The firing valve should be opened gradually when engine is first started. Care should be taken to maintain the temperature of the firebox as nearly uniform as possible. The supply of oil should be gradually increased as the engine increases in speed, in accordance with the requirements of service. Do not force the firing. If the pressure falls back five or ten pounds, restore the maximum pressure by degrees.

Forced firing will fill the flues with soot, overheat the sheets, burn off rivet heads, and cause the boiler to leak.

2. IMPROPER SANDING.—The engine should be well sanded in going from roundhouse to train where practicable, again in pulling out, and several times the first mile or two. This is very important, as engines are more liable to be smoked up in starting the fire and around terminals than after starting. Keep on sanding as long as quantities of black smoke follow the act of sanding. If the supply of sand runs short, you may take it from the main sand box, or get it from cinder pot in front end and use it over again. Always hold the funnel in a position to carry the sand over instead of under the arch.

3. INSUFFICIENT FLOW OF OIL TO BURNER.—Burners are liable to clog up with sand, that is in the oil, of by pieces of waste sucked up by air inlet. A partial or complete stoppage of oil pipe or burner may be overcome by using the blow-back valve. To use this: Open tank valve, close firing valve, and open cock over super-heater. This will blow steam back through oil supply pipe; then close tank valve and open firing valve. This will blow steam through the oil pipe to burner. If the obstruction is not removed by doing this, the pipes will have to be disconnected or atomizer tube removed. Care should be taken to see that this blow-back valve is closed except when used for blowing out pipe and burner. If left open or leaking it will prevent free passage of oil to burner, thereby causing a series of explosions.

Sometimes a partial obstruction may be overcome by closing the air intake valve. This creates a partial vacuum in the burner. If oil flows out of intake pipe it is evident that the obstruction is in the burner.

4. WATER IN OIL.—In case the fire goes out from unknown causes, you should ascertain whether there is water in the oil by opening the drain cock.

Water accumulates in oil tanks sometimes by improper handling of heater. Opening it only a small amount and leaving it on continuously is bad practice. Put it on strong, heat the oil and shut it off. This should be done as much as possible when standing.

5. FALLEN BRICK ON BOTTOM OF FIREBOX OR STRIKING AN OBSTRUCTION, CAUSED BY AN ACCUMULATION OF ASPHALT.—An engine will not make steam well, and will cause an excessive amount of black smoke if the fire drags on bottom or strikes a fallen brick. Roundhouse men should inspect and clean pan under burner thoroughly; crews should inspect and keep it clean. If bricks fall, take them out or push them forward and remove the accumulation of asphalt and sand. The best time to do this is when the fire has just been partially shut off while at a station. Too much attention cannot be given to this point.

6. PARTIAL OR COMPLETE CLOSING OF ATOMIZER TUBE IN BURNER.—If the full opening of the atomizer valve will not remove obstruction, the tube must be taken out of burner. In most engines this can be done in from five to ten minutes.

7. SLIPPING OR WORKING ENGINE HARD WITH FIRE OUT.—Slipping or working the engine hard with the fire out, or starting before the fire is lighted, will cause the flues to leak immediately.

Great care should be exercised to prevent this.

Should it become necessary to do any work inside of the oil tanks after they are empty, first fill the tank with water, put in a few pounds of caustic soda, then turn on steam through the heater pipe until water boils over the manhole. Petroleum contains a greater or less per cent of volatile gases, which are given off at low temperature; therefore, under no circumstances should lighted torches, lamps or lanterns be taken into tanks or near the openings, that have contained crude oil, until they have been thoroughly cleansed.

DONT'S.

Do not leave the fire-door unfastened when starting fire, for, if too much oil is turned on, an explosion may occur, which will drive the flame out of the door, and might injure any one in the cab.

Do not use the blower at any time stronger than is necessary to clear the stack of black smoke, as it is a waste of fuel, makes an unnecessary noise, and, if the fire is burning lightly, will cause the flues to leak.

Do not start the engine without having the firing valve opened sufficiently to insure a good fire, so that the cold air may not be drawn through the flues by the exhaust.

Do not approach a manhole or vent hole in the tank with a lighted torch or lantern nearer than ten feet. To ascertain the amount of oil in the tank, use the stick or rod made for that purpose, carrying it to the light to find the number of inches of oil in the tank.

Do not allow the air cut off from fire by asphalt, sand or pieces of fallen brick accumulating in the pan; hoe it out.

Do not put fire out entirely at any time until engine is put in roundhouse by hostler.

In view of the fact that fuel oil will be used almost exclusively on many divisions in the near future, it is desirable that all concerned become thoroughly familiar with the apparatus pertaining to oil-burning locomotives, to the end that slight defects may be promptly remedied and success in its use assured.

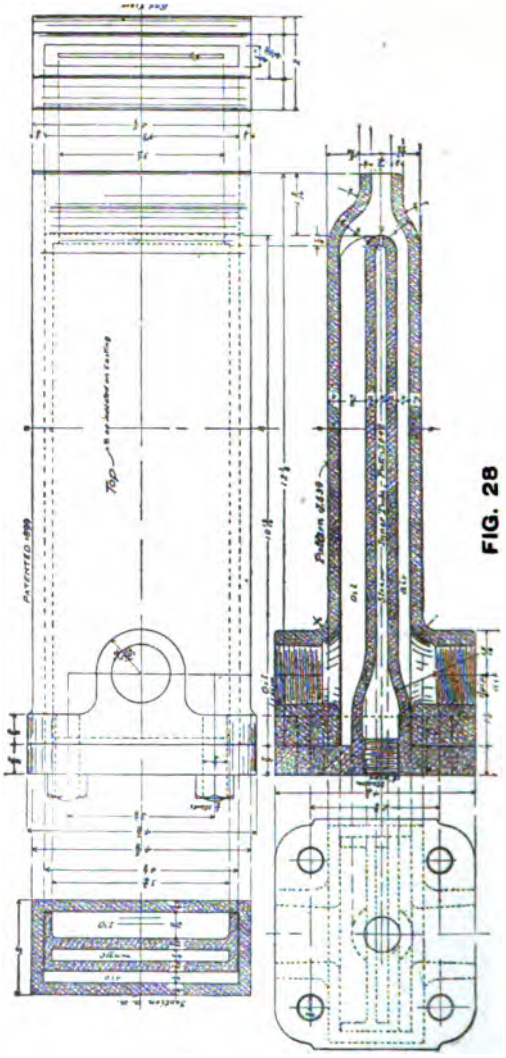


FIG. 28

OIL BURNER — SOUTHERN PACIFIC.
(Three Sizes are used—2", 3" and 4".)

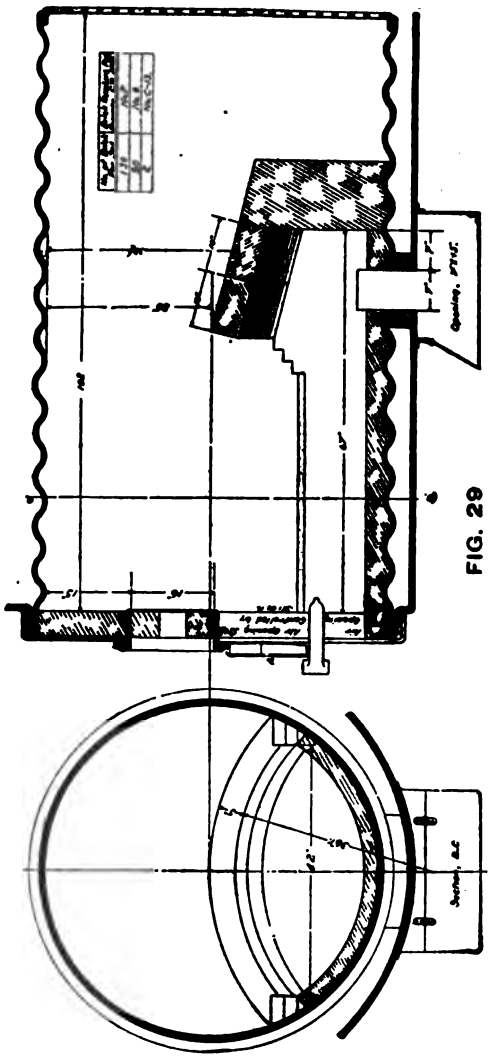


FIG. 29

ARRANGEMENT OF BRICK WORK FOR OIL BURNING LOCOMOTIVES, CLASS E. F.-1, (MOGULS WITH VANDERBILT CORRUGATED FURNACES.)—SOUTHERN PACIFIC.

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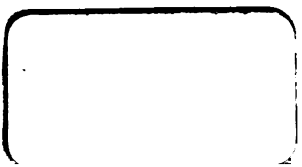
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